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Charles Atwood
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THE

PHILOSOPHY OF STORMS.

By JAMES P. ESPY, A. M.

MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY, AND CORRESPONDING MEMBER OF THE NATIONAL INSTITUTION, WASHINGTON.

Felix qui potuit rerum cognoscere causas.—*Virgil.*

BOSTON:

CHARLES C. LITTLE AND JAMES BROWN.

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PREFACE.

It is now about thirteen years since I became acquainted with Dalton's experiments on the aqueous vapor which exists in the atmosphere. I was much struck with one of his results; namely, that the quantity of vapor in weight, existing at any time in a given space, could be determined with great accuracy in a few minutes, by means of a thermometer and a tumbler of water cold enough to condense on its outside a portion of the vapor in the air. It occurred to me at once, that this was the lever with which the meteorologist was to move the world.

I immediately commenced the study and examination of atmospheric phenomena, determined to discover, if possible, what connection there is between rain and the quantity of vapor, in the atmosphere; but the more facts I collected, whether from my own observations or from those of others, the more contradictory and perplexing they became. It had been long known that vapor is lighter than air, and it was inferred from this, that when a portion of atmospheric vapor is condensed into cloud, the air in the cloud becomes specifically heavier than it was before. This doctrine I received as an axiom, and I never for a moment doubted it, until it occurred to me to calculate the effect which the evolution of the latent caloric produces, during the formation of the cloud.

The result was an instantaneous transition from darkness to light. The moment I saw that a rapidly forming cloud is specifically lighter in proportion as it becomes darker, a thousand contradictions vanished, and the numerous facts, "a rude and undigested mass," which had been stowed away in the secret recesses of my memory, presented themselves spontaneously to my delighted mind, as a harmonious system of fair proportion. It is a most fortunate circumstance that the nature of the theory detailed in the first section is such as to bring order out of confusion, and, when the recipient has become thoroughly acquainted with the elementary principles on which the theory is founded, to cause all the facts, however irregularly they may be communicated, spontaneously to take their appropriate place in the system. Were it not for this, I should fear, that the immense mass of facts detailed in this volume, if read at all, would be read to very little purpose.

I recommend the reader to dwell on that part of the Introduction called the *Synopsis*, and weigh its contents carefully, and return to the same paper after he shall have read the body of the work.

When the summary of the documents of the storm which took place on the 26th January, 1839, was written, it was done under the impression that there would be room for the original documents entire. After it was found that there would not be room, there was not time to write out a more perfect summary. The documents, however, will be preserved for inspection in the archives of the Franklin Institute of Pennsylvania.

I have made the "Report" of the French Academy of Sciences a part of my introduction, not merely for the purpose of showing the reader, that I have the highest authority on my side — for I do not submit to authority myself — but to exhibit a beautiful analysis of my theory, by three of the most distinguished philosophers of Europe.

As a matter of authority, however, I should be justified in bringing forward this "Report" to rebut authority. It had been sneeringly said before a large audience, by a distinguished Professor, that I had failed to convince men of science of the truth of my theory, and that I had appealed to the people, who were incapable of judging. It became, therefore, necessary, to obtain authority against authority.

I say *necessary*, for, if my doctrine is true, it is *infinitely* useful: and therefore it became my duty, *for the sake of mankind*, to use every means in my power to obtain for it a fair and impartial examination, which it was obviously not likely to obtain, while it lay under the imputation of being rejected after examination by the scientific world. I hope, now, that so far as authority is concerned, I stand on at least as high ground as my opponents. Let the theory stand or fall according to its own merits.

I have also inserted the opponent authority of Sir David Brewster. It would appear, however, by an examination of Sir David's statements, that, he has ventured an opinion in favor of both Reid's and Redfield's views, without knowing that those views are inconsistent with each other. Sir David adduced Col. Reid's observations on five water-spouts as proof against my doctrine. Now Col. Reid asserted that all these five turned round, in the same direction, as the hands of a watch.

Again, Sir David says, "The theory of the rotatory character of storms, was first suggested by Col. Capper, but we must claim for Mr. Redfield the greater honor of having fully investigated the subject, and, apparently, established the theory upon an impregnable basis." Surely, Sir David could not have known when he made these assertions that Mr. Redfield insists, in all his writings, on this subject, that all the West India hurricanes and all the tornadoes in this quarter, whirl *contrary* to the hands of a watch! If Col. Reid's observations prove my theory false, what becomes of Mr. Redfield's?

One advantage will most certainly arise from the determined opposition which so many have manifested to my theory: namely, any errors into which I may have fallen either in facts or principles, will be eagerly sought for, detected and exposed, "a consummation devoutly to be wished." After the controversy shall be terminated, and my system admitted to take its place among the acknowledged sciences, it will be time to write out a set of rules to assist the mariner to use the wind in storms to the best advantage.

Indeed, the system is so simple, that the intelligent seaman, without the formality of written rules, will have no difficulty in turning it to practical account, as soon as he becomes acquainted with it.

"*Truth has less of trouble and difficulty, of entanglement and perplexity: of danger and hazard in it.*"[1] Who, that has witnessed it, has not grieved to see the noble mind of many a youth, harassed with the "entanglement and perplexity" of the old system! (201) Much mischief is done by teaching a false system. The time wasted in learning it is not the only evil; by the fruitless efforts of the learner to understand it, his ardor in the pursuit of knowledge, is damped, and he insensibly receives the impression that there is little to choose between truth and falsehood. But let the light of truth pour in fresh on his mind, let him penetrate mysteries heretofore thought inscrutable, — let him see *there* unnumbered contrivances, planned by infinite wisdom and infinite goodness, for the convenience and happiness of man, — let him see that rains and changes of wind are not accidental, but subject to laws as fixed as those which govern the planetary motions, and that these laws are not past finding out; — zeal and animation in the pursuit of knowledge, will then take the place of listlessness and despair.

Among the innumerable benefits arising from the adoption

[1] Tillotson.

of a true system of meteorology, will be the *death of superstition* on this subject. For example, if it is true that a great storm, when once generated, contains a self-sustaining power, and continues for many days and nights in succession, terminating in one place while it is beginning in another, the belief in planetary or lunar influence in the production of this meteor, being incompatible with this single fact, it will be abandoned forever.

I owe an apology to the reader for the frequent repetitions of the elementary principles which he will find in the body of the work.

My apology, I trust, will amount to a justification, when it is known, that the whole work is made up of parts, written at very different periods of time, during the last seven years, according as new storms were investigated, or new facts brought to light.

Now, it was necessary, that each of these parts, which were all intended for separate publication, should contain the elementary principles on which the explanation of the phenomena depends, it follows, either that the publication of the work should be delayed to an unknown period, to give time to remodel the whole, or that the original essays should be published entire. After all, I do not much fear censure on this point, from those who shall read the work with a determination to understand. With *them* the great question will be, is the theory true?

If the evidences which they will find scattered throughout the work, almost with the profusion of nature, though no where centred in one combined phalanx, shall enable them to answer this question in the affirmative; the main purpose for which the work was written will be accomplished; and the magnitude and importance of the truth will leave but little disposition to look censoriously at the mere external form in which that truth is presented.

I have avoided technical language in this work, and I believe there have been used only three terms which need explanation even to the tyro. The latent caloric of steam, or the caloric of elasticity, is that which is required to change water from a fluid to an elastic gaseous state, without increasing its temperature, and the latent caloric of water or the caloric of fluidity, is that which is absorbed by ice when it changes to water, without increasing its temperature. The learner may understand the nature of this latent caloric in the following manner.

Suppose a tin vessel containing a pound of snow at the temperature of zero, Fahr. with a thermometer in it, and the whole placed over some regular source of heat, so as to cause the thermometer to rise one degree every second; at the end of 32 seconds the thermometer will be at 32°. Suppose now the caloric to continue to enter the vessel with the same rapidity, the thermometer will remain stationary at 32° for 140 seconds, and at the end of this time the snow will all be melted. The caloric which went into the snow to melt it, is called 140° of *caloric of fluidity.*

As soon as the snow is all melted, the thermometer will begin to rise again, and continue to rise one degree every second for 180 seconds, provided the barometer stands at 30 inches, and the caloric flows in with the same velocity, it will then be at the temperature of 212°; at which point it will stand for 1030 seconds, and during all this time the water will constantly be changing to steam or vapor, and at the end of 1030 seconds it will all be evaporated. The caloric which entered the water during this change, is called the *caloric of elasticity.*

The *specific caloric* of a body is its capacity of being heated, as compared to that of water. For example; if the same quantity of caloric which heats a pound of water one degree will heat a pound of air 4°, the *specific caloric* of air is called 0.25.

CONTENTS.

SECTION SIXTH.

SECTION SEVENTH.

SECTION EIGHTH.

SECTION NINTH.

SECTION TENTH.

APPENDIX.

INTRODUCTION.

"Every beginning is difficult;" and to render the following work, which is the beginning of our knowledge on the causes of storms, the more easy to be comprehended, I have thought proper, even at the expense of much repetition, to give in advance a general outline of the whole theory, in one connected chain of cause and effect, following nature in her manner of operating, in producing these meteors.

The paper which was read to the British Association, in September, 1840, contains this outline; and, as the whole work is intended both to develop the cause of storms, and to exhibit the manner in which, according to the strict rules of induction, the development was gradually made, I present that paper here, as an introduction to the whole.

Mr. Espy's paper "On Storms," which excited much attention, was appointed for half past twelve o'clock, and that hour having now arrived, the President, Professor Forbes, called on Mr. Espy, who commenced by stating that he had found by examining simultaneous observations in the middle of storms, and all round their borders, that the wind blows inward on all sides of a storm towards its central parts; towards a point if the storm is round, and towards a line, if the storm is oblong, extending through its longest diameter. Mr. Espy stated that he had been able to investigate

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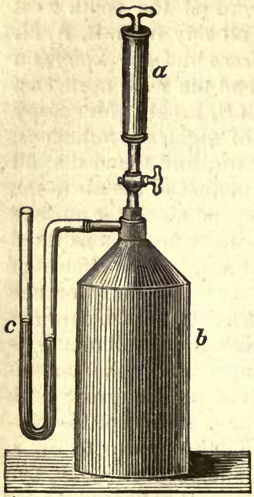


calculations made on chemical principles. Mr. Espy exhibited the mode of operating with this instrument.

By means of the condensing pump *a*, air may be forced into the glass vessel *b*, and its degree of condensation can be measured by the barometer gage *c*.

After the instrument is charged, the stop-cock is turned, and the pump removed. When the air within acquires the temperature of the air without, a measure is carefully applied to the barometer gage to ascertain how much higher the mercury stands in the outer leg than in the inner; the cock is then turned, and the air permitted to escape, and at the moment of equilibrium, the cock is closed again. Now as the cock is closed at the moment the greatest cold is produced by expansion, the mercury in the outer leg will begin to ascend, and that in the inner leg to descend, because the air within receives heat from without, and the difference of level being measured as before, will indicate the number of degrees cooled by a given expansion.

Mr. Espy shewed that when dry air is used in the experiment, the temperature is reduced about twice as much as when moist air is used, on account of latent caloric evolved in the latter case by the formation of cloud which is plainly visible. (59.) Mr. Espy then proceeded to give the following synopsis of his theory, premising that the numbers he should introduce were not intended to be strictly accurate, and would be subject to many corrections — one in particular, in which no notice had been taken of the specific heat of air under different pressures.

SYNOPSIS.

When the air near the surface of the earth becomes more heated or more highly charged with aqueous vapor, which is only five-eighths of the specific gravity of atmospheric air, its equilibrium is unstable, and up-moving columns or streams will be formed. As these columns rise, their upper parts will come under less pressure, and the air will therefore expand; as it expands, it will grow colder about one degree and a quarter for every hundred yards of its ascent, as is demonstrated by experiments on the nephelescope, (58 to 68.) The ascending columns will carry up with them the aqueous vapor which they contain, and, if they rise high enough, the cold produced by expansion from diminished pressure will condense some of this vapor into cloud; for it is known that cloud is formed in the receiver of an air pump when the air is suddenly withdrawn. The distance or height to which the air will have to ascend before it will become cold enough to begin to form cloud, is a variable quantity, depending on the number of degrees which the dew point is below the temperature of the air; and this height may be known at any time by observing how many degrees a thin metallic tumbler of water must be cooled down below the temperature of the air before the vapor begins to condense on the outside. The highest temperature at which it will condense, which is variable accordingly as there is more or less vapor in the air, is called the "dew point," and the difference between the dew point and the temperature of the air in degrees, is called the complement of the dew point.[1] (117, 118, 129.)

It is manifest, that if the air at the surface of the earth should at any time be cooled down a little below the dew point, it would form a fog, by condensing a small portion of its transparent vapor into little fine particles of water; and if it should be cooled twenty degrees below the dew point, it would condense about one half its vapor into water, and at forty degrees below, it would condense about three fourths of its vapor into water, &c. This, however, will not be exactly the case from the cold produced by expansion in the upmoving columns; for the vapor itself grows thinner, and the dew point falls about one quarter of a degree for every hundred yards of ascent.

It follows, then, as the temperature of the air sinks about one degree and a quarter for every hundred yards of ascent, and the dew point sinks about a quarter of a degree, that as soon as the column rises as many hundred yards as the complement of the dew point contains degrees of Fahrenheit, cloud will begin to form; or, in other words, the bases of all clouds forming by the cold of diminished pressure from upmoving columns of air, will be about as many hundred yards high as the dew point in degrees is below the temperature of the air at the time. (66, 67, 97). If the temperature of the ascending column should be ten degrees above that of the air through which it passes, and should rise to the height of 4,800 feet before it begins to form cloud, the whole column would then be 100 feet of air lighter than surrounding columns; and if the column should be very narrow, its velocity of

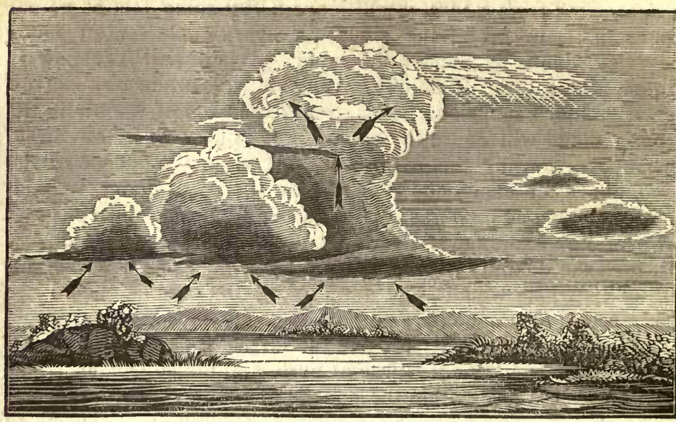
[1] The height of the bases of forming cumuli may be ascertained by the following empirical formula: $10300 \left(\frac{t-t'}{t'}\right) =$ height of base in yards; t being the temperature of the air in degrees of Fahrenheit, and t' the temperature of wet bulb swung briskly in the air. (66, 98.)

upward motion would follow the laws of spouting fluids, which would be eight times the square root of 100 feet a second, that is, 80 feet a second, and the barometer in the centre of the column at its base would fall about the ninth of an inch. As soon as cloud begins to form, the caloric of elasticity of the vapor or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapor. This will prevent the air, in its further progress upwards, from cooling so fast as it did up to that point; and, from experiments on the nephelescope, it is found to cool only about one half as much above the base of the cloud as below; that is, about five eighths of a degree for one hundred yards of ascent, when the dew point is about seventy degrees. If the dew point is higher, it cools a little less, and if the dew point is lower, it cools a little more than five eighths of a degree in ascending one hundred yards.

Now, it has been ascertained by aeronauts and travellers on mountains, that the atmosphere itself, free from clouds, is about one degree colder for every hundred yards in height above the surface of the sea; therefore, as the air in the cloud above its base is only five eighths of a degree colder for every hundred yards in height, it follows, that when the cloud is of great perpendicular height above its base, its top must be much warmer than the atmosphere at that height, and consequently much lighter. Indeed, the specific gravity of a cloud of any height, compared with that of the surrounding air at the same elevation, may be calculated, when the dew point is given; for its temperature is known by experiments with the nephelescope, and the quantity of vapor condensed by the cold of diminished pressure at every point in its upward motion, and of course the quantity of caloric of elasticity given out by this condensation is known, and also the effect this caloric has in expanding the air receiving it, beyond the volume it would have if no caloric of elasticity was evolved in the condensation of the vapor. (175.) For example, according to the experiments of Professor W. R. Johnson, of Philadelphia, a pound of steam, at the temperature of 212°, contains 1,030° of caloric of elasticity; and as the sum of the latent and sensible caloric of steam is the same at all temperatures, it follows, that a pound of steam being condensed in 1,210 pounds of water at 32°, would heat this water up one degree; and, as the specific caloric of air is only 0.267, if a pound of vapor should be condensed in 1,210 pounds of air, it would heat that air nearly 4°, or, which is the same thing, it would heat 100 pounds of air about 45°. And in all these cases it would expand the air about 8,000 times the bulk of water generated; that is, 8,000 cubic feet for every cubic foot of water formed out of the condensed vapor. And as it requires about 1,300 cubic feet of vapor, at the ordinary temperatures of the atmosphere, to make one cubic foot of water, if this quantity be subtracted from 8,000, it will leave 6,700 cubic feet of actual expansion of the air in the cloud, for every cubic foot of water generated there by condensed vapor. When hail or snow is formed, the caloric of fluidity given out will produce about an eighth greater expansion. This great expansion of the air in the forming cloud will cause the air to spread outwards in all directions above, causing the barometer to rise on the outside of the cloud, above the mean, and to fall below the mean under the middle of the cloud as much as it is known to do in the midst of great storms. For example, if the dew point should be very high, say 78°, then the quantity of vapor in the air would be about one fiftieth of its whole weight, and if the upmoving column should rise high enough to condense one half its vapor into cloud, it would heat the air containing it 45°, and the air so heated would be $\frac{45}{448}$ larger than it would be if it was at zero, and not so heated. And if we assume a case within the bounds of nature, and suppose the cloud and the column under the cloud to occupy three fourths of the whole weight of the atmosphere, or in other words, if we suppose the top of the cloud to reach a height where the barometer would stand at $7\frac{1}{2}$ inches, and the mean temperature of the whole column 40° warmer than the surrounding air, (which we may suppose, for the sake of illustration, to have a mean temperature of zero,) then would the barometer fall under the cloud at the surface of the earth $\frac{40}{488}$ of 22.5 inches or a little more than an inch and eight tenths.[1]

Though the air will be driven up much higher than the point here assumed, and of course, increase the depression of the barometer, from its specific levity, the cloud will cease to form at greater heights, because the dew point, at these great elevations, falls by a further ascent as rapidly as the temperature ; and at greater elevations, it will even fall more rapidly. If, for instance, the air should rise from where the barometer stands at 6 inches, to where it stands at 3 inches, the dew point would fall about 20°, but the temperature would fall less than 20°, and therefore no vapor would be condensed by such ascent. When a cloud begins to form from an ascending column of air, it will be seen to swell out

[1] *Sittings of the French Academy of Science*, 1839, *page* 715. M. Fournet says, that the parasite clouds which are formed over Mount Pilat do not always redissolve immediately after having been carried beyond the place of their birth, and that the formation of this kind of cloud is accompanied by a very considerable local depression of the barometer. If the formation of a small parasitic cloud produces a considerable depression of the barometer, what ought a great storm cloud to do ?



at the top, assuming, successively, the appearances of 1, 2, 3, generally called cumuli : or, if the upmoving current should be driven out of its perpendicular motion by an upper current of air, the clouds which might then form would be ragged and irregular, called broken cumuli, as 4. These will always be higher than the base of cumuli, but much lower than cirrus. While the cloud continues to form and swell up above, its base will remain on the same level, for the air below the base has to rise to the same height before it becomes cold enough, by diminished pressure, to begin to condense its vapor into water ; this will cause the base to be flat, even after the cloud has acquired great perpendicular height, and assumed the form of a sugar loaf. Other clouds, also, for many miles around, formed by other ascending columns, will assume similar appearances, and will moreover have their bases all on the same or nearly the same horizontal level ; and the height of these bases from the surface of the earth will be greatest about two o'clock, when the dew point and temperature of the air are the greatest distance apart.[1] The outspreading of the air in the

[1] *On some Meteorological Phenomena observed in the Pyrenees*, by M. Peytier. The geodisic observations, says M. Peytier, that I have made with M. Hossard in the western part of the chain of the Pyrenees, (from the Garronne as far as Saint Jean de Luz,) during the years 1825, '26, and '27, having placed me under the necessity of encamping on the principal mountains of this part of the chain, I have had occasion to make some observations on several meteorological phenomena of some interest, of which I will give an account. 1st. On the clouds. It is extremely rare that there is not any cloud on the chain of the Pyrenees ; thus, during the summer of 1826, I saw

upper parts of an ascending column will form an annulus all round the cloud, under which the barometer will stand above the mean; of course the air will sink downwards from its greater weight in the annulus, and increase the velocity of the wind at the surface of the earth, towards the centre of the ascending column, while all round on the outside of the annulus there will be a gentle wind outwards. Any general currents of air, which may exist at the time, will of course modify these motions, from the oblique forces they would occasion. The upmoving current of air

only four days without any clouds: the 12th of May, the 16th of June, the 30th of July, and the 7th of August.

It is in the morning, at the rising of the sun, that the mountains are seen most frequently without clouds, but it is excessively rare that they are not covered before the middle of the day.

When the mountains are seen in the morning, we observe generally at one, two, or three hours, more or less, after the rising of the sun, when the heat begins to be felt, there form in the plains at the foot of the chain, some little clouds, which rise gradually and reach the mountains. If we were placed on a high mountain, we would see these little clouds form and rise sometimes as rapidly as rockets. They group themselves in the mountains, where they frequently form tempests; at other times, they rise slowly, assemble in a mass, on the same level, and form a stratum more or less thick and more or less elevated, that covers the plain and resembles a sea of white vapors.

This stratum, thus formed, rises gradually during the day, (sometimes more than 1000 metres,) and lowers in the evening and in the night. Often, this stratum of clouds rising in the day and lowering at night, remains thus for several days in succession. Very often the clouds dissolve in the night and form again in the day some time after the rising of the sun.

These clouds, when they rise in the mountains, generally follow the direction of the valleys, though the wind has not that direction.

We remarked often in the high valleys some clouds leaning against the two sides of the mountains, whilst the heavens were seen above from the middle of the valley, between the two bands of clouds.

We see again, frequently, a cap of clouds on some elevated peaks, when there are not any on the mass of the chain. Often the clouds cover all one side of the chain, whilst the other side is without any clouds; and we remarked that the side toward France is more often covered than that toward Spain.

These clouds are sometimes seen to ride on the summit of the chain. This happens, when pushed by the wind, the clouds attain the top of the chain, where their weight causes them to fall back to the other side.

We remarked also, sometimes, two strata of clouds moving in different directions. There is then some probability of a change of weather.

When there are two strata of clouds plainly shown, the upper is generally higher than the summit of the chain; it rarely touches the peaks. The difference of the level between the two strata is often very considerable.

These clouds are not level in the rainy weather; they are generally low in time of rain, and much more elevated in storms.

The composition of these clouds does not always appear to be the same; sometimes they are light and transparent, sometimes they are thick and not transparent, and sometimes they are dry, and at other times very humid. I have seen the rain producing the rainbow; this is when a part of the cloud resolves itself into excessively fine rain.

The clouds which produce these haloes, appear very elevated, very light, and very transparent.

must of course be entirely supplied by the air within the annulus, and that which descends in the annulus itself. When upmoving currents are formed by superior heat, clouds will more frequently begin to form in the morning, increase in number as the heat increases, and cease altogether in the evening, when the surface of the earth becomes cold by radiation.

The commencement of up-moving columns in the morning, will be attended with an increase of wind, and its force will increase with the increasing columns; both keeping pace with the increasing temperature. This increase of wind is produced partly by the rush of air on all sides at the surface of the earth towards the centre of the ascending columns, producing fitful breezes; and partly by the depression of air all round the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface.[1] The rapid disturbance of equilibrium, which is produced by *one* ascending column, will tend to form *others* in its neighborhood ;[2] for, the air being pressed outwards from the annulus, or at least retarded on the windward side, will form other ascending columns, and these will form other annuli, and so the process will be continued. These ascending columns will have a tendency to approach, and finally unite; for the air between them, as between 2 and 3, (p. xii.) must descend, and in descending, the temperature of the whole column will increase,

[1] On the comparative force of the wind during the twenty-four hours, by Mr. Osler.

Mr. Follett Osler, brought before the British Association, a paper, in which he gave the results of his investigations respecting the direction and force of the wind, deduced from the mean of 26,000 hourly observations, taken by the anemometer, at the Philosophical Institution, at Birmingham, during the years 1837–8, and 1839. We extract one of Mr. Osler's tables.

Table, showing the Relative Force of the Wind for each hour of the day, distinguishing the Seasons; from a mean of the years 1837–8, *and* 1839.

	1 a.m.	2	3	4	5	6	7	8	9	10	11	12	1 p.m.	2	3	4	5	6	7	8	9	10	11	12
Winter.	55	54	49	47	47	48	48	51	50	67	73	82	89	89	85	70	75	65	63	63	63	59	61	57
Spring.	26	28	28	27	29	29	32	41	56	70	80	82	90	89	89	80	81	72	52	45	46	38	33	29
Summer.	19	19	19	19	22	20	18	21	25	40	47	55	58	54	53	44	34	28	27	24	22	19	21	20
Autu . n.	19	19	19	19	22	20	18	21	26	40	47	55	58	54	53	44	34	28	27	24	22	20	21	20
Totals,	119	120	115	112	120	117	116	134	157	217	247	274	295	286	280	247	224	193	169	156	153	136	136	126

As direction is not regarded in this table, a total of more than one thousand observations is given for each hour of the day. In tabulating these, the curve obtained, is found to be almost identical with that of the thermometer — not only for the whole year, but for each season. The increase in the temperature, however, precedes the rise of the wind by a short interval, until it has attained its maximum force; but as evening approaches, the wind declines more rapidly than the temperature.

[2] The annexed figure, is a copy of three water-spouts, seen by Lieut. Ogden, at one time, on the edge of the Gulf stream, which is described at page

for it is known that the air, at great elevations, contains more caloric to the pound, than the air near the surface of the earth, because it is the upper regions that receive the caloric of elasticity, given out in the condensation of vapor into clouds. Therefore, when the air has descended some time in the middle, between two ascending columns, the barometer will fall a little, or at least not stand so high above the mean as it does on the outside of the two clouds, and so the columns will be pressed towards each other. If one of two neighboring columns should be greatly higher than the other, as 3 and 2, (p. xii.) its annulus may overlap the smaller one, and, of course, the current under the smaller cloud will be inverted, and the cloud which may have been formed over the column thus forced to descend will soon disappear ; for as it is forced downwards by the overlapping annulus of the more lofty column, it will come under greater pressure, and its temperature will be thus increased ; and it is manifest, that as soon as its top descends as low as its base, it will have entirely disappeared ; and, in the mean time, the larger cloud will have greatly increased.

As the air above the cloud formed by an ascending column is

57. For an account of the manner in which one spout, while forming, tends to generate others in its neighborhood, see page 435.

forced upwards, if it contains much aqueous vapor, a thin film of cloud, as over the top of 2, (p. xii.) will be formed in it by the cold of diminished pressure, entirely distinct from the great dense cumulus below; but as the cumulus rises faster than the air above it, (for some of the air will roll off) the thin film and the top of the cumulus will come in contact; and sometimes a second film or cap may be formed in the same way, and perhaps a third and fourth. When these caps form, there will probably be rain, as their formation indicates a high degree of saturation in the upper air. (96.)

When the complement of the dew point is very great, (twenty degrees and more) clouds can scarcely form; for up-moving columns will generally either come to an equilibrium with the surrounding air, or be dispersed before they rise twenty hundred yards, which they must do in this case, before they form clouds. Sometimes, however, masses of air will rise high enough to form clouds; but they are generally detached from any up-moving column underneath, and of course cannot then form cumuli with flat bases; such clouds will be seen to dissolve as soon as they form, and even while forming, they will generally appear ragged, thin, and irregular. Moreover, if the ground should be colder during the day, than the air in contact with it, as it sometimes happens after a very cold spell of weather, then, as the air touching the cold earth will be colder than the stratum above it, ascending columns cannot exist, and of course no cumuli can be formed on that day, even though the air may be saturated with vapor to such a degree as to condense a portion of it on cold bodies at the surface of the earth. Also, if during the whole winter, any part of Siberia, or the northern part of North America, should be so much colder than surrounding regions, that no up-moving columns could be produced, then neither clouds nor snow could be formed.[1] Neither can clouds form of any very great size, when there are cross currents of air sufficiently strong to break in two an ascending current, for the ascensional power of the up-moving current will thus be weakened and destroyed. Immediately after a great rain, too, when the upper air has yet in it a large quantity of caloric, which it received from the condensation of the vapor, the up-moving columns which may then occur, on reaching this upper stratum, will not continue their motion in it far, from the want of buoyancy; therefore, they will not produce rain, nor clouds of any kind, but broken cumuli. Besides, as the air at some distance above the surface of the earth, and below the base of the cloud,

[1] There is a district in Siberia, mentioned by Erman, where, during winter, snow never falls, and clouds are unknown. Report of Committee of Royal Society on Physics and Meteorology, page 45.

is sometimes very dry, and as much of this air goes in below the base of the cloud and up with the ascending column, large portions of the air in the cloud may thus not be saturated with vapor, and, of course, rain in this case will not be produced. Professor Stevelly, of Belfast, told the author, that he knew that clouds are sometimes not saturated. These are some of the means contrived by nature to prevent up-moving columns from increasing until rain would follow. Without some such contrivances, it is probable that every up-moving column which should begin to form cloud when the dew point is favorable, would produce rain, for as soon as cloud forms, the up-moving power is rapidly increased by the evolution of the caloric of elasticity.

On the leeward side of very lofty mountains, there cannot be rain; for as the air on the windward side rises up the sides of the mountain, it will condense all the vapor which can be condensed by the cold of diminished pressure, before it reaches to the top, and even if cloud passes over the top to the other side, it would soon disappear, because in passing down the slope it will come under greater pressure, and thus be dissolved by the heat produced. These are some of the causes which prevent rains at particular times and in particular localities. If, however, the air is very hot below, with a high dew point, and no cross currents of air above to a great height, then, when an upmoving current is once formed, it will go on and increase in violence as it acquires perpendicular elevation, especially after the cloud begins to form. At first the base of the cloud will be flat; but after the cloud becomes of great perpendicular diameter, and the barometer begins to fall considerably, as it will do from the specific levity of the air in the cloud, then the air will not have to rise so far as it did at the moment when the cloud began to form, before it reaches high enough to form cloud from the cold of diminished pressure. The cloud will now be convex below, assuming successively the

6 7 8

appearances 6 and 7, and its parts will be seen spreading outwards in all directions, especially on that side towards which the upper current is moving, assuming something of the shape of a mushroom. In the mean time, the action of the in-moving current below, and upmoving current in the middle, will become very violent, and if the barometer falls two inches under the centre of the cloud, the air, on coming in under the cloud, will cool by diminished pressure about ten degrees, and the base of the cloud will reach the earth, if the dew point was only eight degrees below the temperature of the air at the time the cloud began to form. The shape of the lower part of the cloud will now be that of an inverted cone with its apex on the ground, as 8, and when a little more prolonged and fully developed, it will be what is called a tornado if it is on land, and a water-spout if at sea.

On visiting the path of a tornado, (see the whole of section VII.) the trees on the extreme borders will all be found prostrated with their tops inwards, either inwards and backwards, or inwards and forwards, or exactly transverse to the path. The trees in the centre of the path will be thrown either backwards or forwards, or parallel to the path; and invariably if one tree lies across another, the one which is thrown backwards is underneath. Those materials on the sides which are moved from their places and rolled along the ground, leaving a trace of their motion, will move in a curve convex behind, those which were on the right hand of the path will make a curve from left hand to right, and those on the left hand of the path will make a curve from right hand to left; and many of these materials will be found on the opposite side of the path from that on which they stood on the approach of the tornado, being carried beyond the centre by their momentum, and moved a little forward by the rear of the tornado. Also those bodies which are carried up will appear to whirl, unless they arise from the very centre; those that are taken up on the right of the centre will whirl in a spiral from left to right, and those on the left of the centre will whirl in a spiral upwards from right to left. On examining the trees which stand near the borders of the path, it will be found that many of the limbs are twisted round the trees, and broken in such a manner as to remain twisted, those on the right side of the path from left to right, and those on the left side of the path from right to left. However, it will be found that only those limbs which grew on the side of the tree most distant from the path of the tornado are broken; for those alone were subject to a transverse strain. The houses which stood near the middle of the path will be very liable to have the roofs blown up, and many of the walls will be prostrated, all outwards, by the explosive influence of the air within, and those houses covered with zinc or tin, from being air tight, will suffer most.[1] The floors from the cellars will also frequently be thrown up, doors and windows burst outwards, and bureaus and corks of empty bottles exploded. (181.) All round the tornado at a short distance, probably not more than three or four hundred yards, there will be a dead calm, on account of the annulus formed by the rapid efflux of air above, from the centre of the upmoving and expanding column. In this annulus the air will be depressed, because the barometer stands above the mean there, and all round on the outside of it, at the surface of the earth, there will be a gentle wind outwards, and of course all the air which feeds the tornado is supplied from within the annulus. Nor is this difficult to understand, when the depression of the air in the annulus is considered, for any amount may be thus supplied by a great depression. Light bodies, such as shingles, branches of trees, sand, pollen of plants in bloom, grain, fishes,[2] frogs, and tadpoles, (82) and drops of rain or water formed in the cloud, will be carried up to a great height, before they are permitted to fall to the earth, provided there is no whirl to throw them out by a centrifugal force ; (32, 33,) for though they may frequently be thrown outwards above, and then descend to a considerable distance at the side, they will meet with an in-blowing current below, which will force them back to the centre of the upmoving current, and so they will be carried aloft again. (32, 82.)

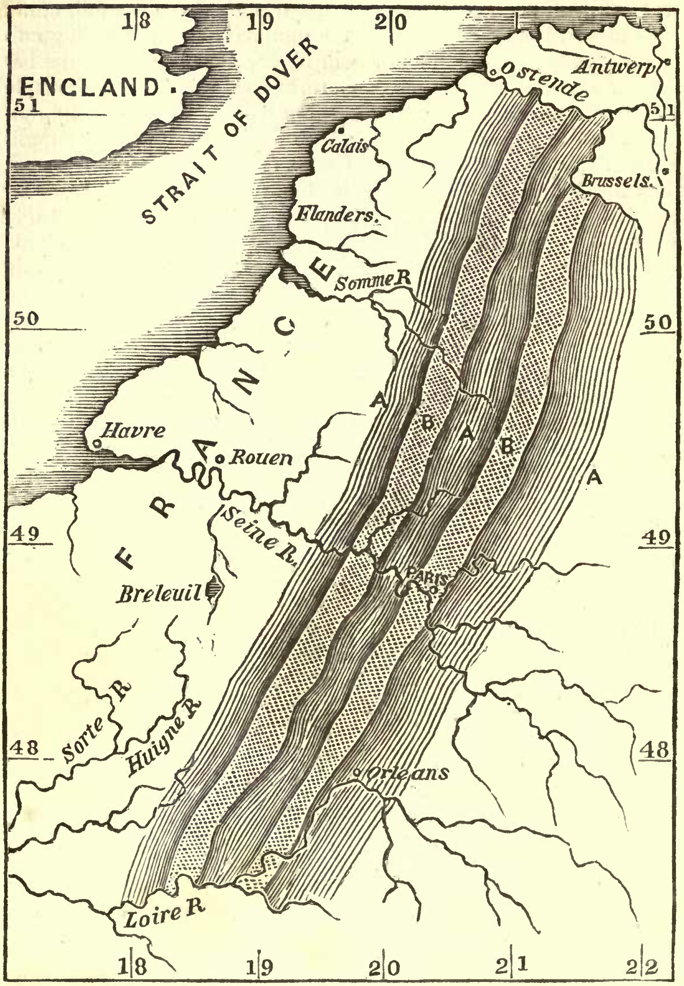
The drops of rain, however, will frequently be carried high enough to freeze them, especially if they are thrown out above so far as to fall into clear air, for this air will in some cases be thirty or forty degrees colder than the air in the cloud. In this case, if the upmoving column is perpendicular, the hail will be thrown out on both sides, sloping inwards as it falls ; (183 end) and on examination it will be found that two veins of hail fell simultaneously, at no great distance apart.[3] This hail will frequently be found to

[1] Professor Fisher told me that he knew several instances, in Baltimore, of zinc roofs being carried away, while others, in their neighborhood, not air tight, were undisturbed.

[2] While this article is in the press, June 30, 1841, a shower of fishes (one a squid ten inches long) fell in Boston, and the hail stones which fell at the same place had a saline taste. It was nearly calm at the time, but the wind was very violent in the neighborhood.

[3] The annexed chart is copied from the memoirs of the French Academy, vol. 90. It represents two veins of hail which fell simultaneously not more than eight minutes at any one place, travelling from the Pyrenees to the Baltic with a velocity of about 50 miles an hour. A A A are veins of rain ; B B are veins of hail. (69.)

contain many of the materials which were carried up from the surface of the earth; (45) and in cases of violent action, sheets of water will be frozen into cakes of ice, which will break into all sorts of shapes and angles on reaching the surface of the earth.[1]



[1] Mr. Howard says, " On the 21st of June, 1817, the thermometer at Bath in the shade stood at 86°, and on the same day at Lyneham, a water spout inundated a considerable quantity of land and occasioned a rapid rise of the Avon. At

It is indeed probable, (32, 33, 45,) that in all violent thunder storms in which hail falls, the up-moving current is so violent as to carry drops of rain to a great height, when they freeze and become hail. It is difficult, if not impossible, to conceive any other way in which hail can be formed in the summer, or in the torrid zone. (45.) In those countries in which an upper current of air prevails in a particular direction, the tornadoes and water-spouts will generally move in the same direction, because the up-moving column of air in this meteor rises far into this upper current, and of course its upper part will be pressed in this direction, and as the great tornado cloud moves on in the direction of the upper current, the air at the surface of the earth will be pressed up into it by the superior weight of the surrounding air. It is for this reason that the tornado in Pennsylvania generally moves towards the eastward, (*passim.*) The *lower* current does not give direction to the hurricanes of the West Indies, for in the latitude of 15, north,

Salisbury, the storm commenced about 2, P. M., with almost an instantaneous darkness, and a violent rushing of the wind from the N. E. accompanied by sheets of water and large pieces of ice. About 3, the wind ceased from the N. E., and suddenly it commenced blowing from the S. W. with such torrents of rain for more than half an hour, that every street was flooded, and the water ran through many of the houses. And at Gloucestershire, on the night of the 15th July, 1808, masses of ice from three to nine inches in circumference did great damage. They appeared like fragments of a vast plate of ice, broken into small masses. The storm rose in the S. W., and died away in the N. E., from which quarter it was opposed by a strong breeze. A similar hail storm, with *rugged pieces of ice*, is mentioned in the 2d vol. page 73 ; and in page 131, he mentions hail stones five inches long and two inches in diameter, which fell in France in the Upper Morne. And in page 127, he says, pieces of ice of prodigious size fell near Birmingham. In p. 257, the Ohio storm, with stones 13, 14 and 15 inches in circumference, some appeared like snow balls immersed in water and then frozen. Also in page 271, mention is made of hail falling a foot deep, in less than 10 minutes, and becoming a solid mass of ice. Page 319. M. Howard says, the hail stone, which Gilbert mentions as exceeding the strength of eight men to lift it, was doubtless formed of agglutinated hail melting on the surface and freezing within.

In the Orkney spout of the 24th July, 1818, (36,) instead of hail stones of the usual shape "pieces of ice," of almost all forms, were precipitated with the utmost violence. Mr. Caithness attempted to wade out among the hail stones in the direction of the cattle, but the loose ice, he says, slipped below his feet, and sometimes reached his knees. In this way his legs were so much cut by its sharp edges that he was soon obliged to desist.

Many of these stones were not unlike thick, clumsy oyster shells. The whole extent of this hail storm from S. W. to N. E. was little more than 20 miles, and travelled this space at the rate of about a mile in a minute and a half, and lasted, at any one place, not more than eight or nine minutes. The barometer fell from 29.68 to 27.76, on the passage of the spout; or perhaps more, as the minimum may not have been observed, for it did not occur to Mr. Lindsay to note the barometer till the cloud was passing off; sixty geese in one flock were killed, and all the rest so hurt that they soon died ; and the milch cows "were struck yeld," or gave no more milk, and indeed would not suffer the people to attempt to milk them any more.

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the prevailing direction of the trade winds is north easterly, and there the hurricanes move towards the north west. It is probable, however, they sometimes bend out of their course, to pass over an island, lying near the track, which they would otherwise pursue.

If a tornado should stop in its motion for a few seconds, as it might do, on meeting with a mountain, it would be likely to pour down an immense flood of water or ice, in a very small space, for the drops which would be carried up by the ascending current would soon accumulate to such a degree as to force their way back, and this they could not do without collecting into one united stream of immense length and weight, and of course on reaching the side of the mountain ; this stream, whether it consisted of water or hail, would cut down into the side of the mountain a deep hole, and make a gully all the way to the bottom of the mountain, from the place where it first struck. (192 to 200.)

As the air spreads out more rapidly above than it runs in below, there will be a tendency in storms to increase in diameter, and this tendency will be greater on the north side than on any other, for the efflux above finds less resistance on that side, for a reason assigned in the next paragraph ; therefore it is probable that storms become elongated north and south, and then, if they move towards the east, they must travel side foremost.

At the equator, or at least those parts of it where the trade winds are constant from east to west, it is probable tornadoes travel from east to west. (147.) For as the air in the torrid zone is about 80° in temperature at a mean, and the air in the frigid zone is about zero, the air in the torrid zone is constantly expanded by heat about $\frac{80}{448}$ of its whole bulk in the frigid zone. This will cause the air at the equator to stand more than seven miles higher from the surface of the earth to the top of the atmosphere than at the north pole. The air, therefore, will roll off from the torrid zone both ways towards the poles, causing the barometer to fall in low latitudes, and rise above the mean in high latitudes. This will cause the air to run in below towards the equator, and of course rise there. Now from the principle of the conservation of areas, it will recede more and more to the west as it rises, and of course the upper current of the air, at the equator, probably moves towards the west. However, as the air rolls off above, towards the north, it will be constantly passing over portions of the earth's surface, which have a less diurnal velocity than the part from which it set out, and as from the nature of inertia it still inclines to retain the diurnal velocity towards the east, which it originally possessed, when it reaches the latitude of about 20 or 25 degrees, it will then probably be moving nearly towards the north, and beyond that latitude its motion will be north easterly. The effect of the air rolling off above from the equator towards the poles, when considered alone, would cause the barometer at the very poles to stand above the mean; but the centrifugal force of the air in the frigid zone, arising from the diurnal revolution of the earth on her axis, produces a countervailing force of considerable power, and flattens the atmosphere at the poles more than the earth is flattened, because it is of greater diameter, and perhaps this may cause the barometer to stand below the mean very near the poles. Let this matter be further examined. As the air in the torrid zone certainly does rise and run out towards the poles above, it *must rise* there in columns and not all over the zone at once, otherwise this whole zone would be covered with eternal cloud, formed by the condensation of the vapor from the cold of diminished pressure as the air ascended.

If violent storm clouds, which necessarily rise to a great height in the upper current, are driven forward in the direction of the upper current, it is probable that the barometer will rise higher in that part of the annulus which is in front of the storm, than in the rear, and if so, a sudden rise of the barometer, in particular localities, may become, when properly understood, one of the first symptoms of an approaching storm. (116 Rationale, 170.) In consequence of the high barometer in front of the storm in a semi-annulus, the air will be forced downwards there, and cause, in some cases a more violent action of the air or wind backwards, meeting the approaching storm, than will be experienced in the rear of the storm. As the barometer will probably be highest in the centre of the semi-annulus, north east of the storm, in middle latitudes, the tendency of the wind to blow outwards on all sides from the region where the barometer stands highest, may cause the wind in the beginning of the storm to blow so as to appear to whirl from left to right, on the east side of the storm, and from right to left on the west side. (p. 240.)

As the air comes downwards in the semi-annulus in front of the storm, it will come under greater pressure, and therefore any clouds which it may contain will probably be dissolved by the heat of greater pressure;[1] consequently, on the passage of the annulus it will probably be fair weather. (p. 241.) Also, as the air above always contains more caloric to the pound than the air below, more especially that which has just spread out above from a storm cloud, containing the caloric recently evolved from the condensing vapor, there will be an increase of temperature on the passage of the annulus, partly from the increased pressure, partly from the increased radiation of the hotter air above, (p. 288) but chiefly by the descent of the air itself. In very hot climates, this

[1] An air tight piston, moved in a glass cylinder, will cause a cloud to appear, by rarefying the air; and to disappear, by condensing it.

increase of temperature in front of the storm will be very sensibly felt. (page 241.) The increased pressure in the annulus round a volcano, when it suddenly bursts out, will sometimes, under favorable circumstances, be very great, and of course the air will be depressed from a great height; so that some portion of the very air which has gone up in the central parts of the ascending column, and formed cloud by the cold of diminished pressure, may be forced down to the surface of the earth, bringing with it the caloric of elasticity which it received from the condensing vapor; if so, the heat experienced at the time of this descent will be very great.

These hot blasts of air will alternate with cold blasts; for the air which is forced down from great heights in the annulus will not only be very hot, but very dry, having condensed its vapor in its previous ascent. Now, when this hot dry air flows inwards again towards the volcano, and ascends, it will not form cloud, because of its want of vapor, and therefore the process of cloud-forming will cease, and consequently hail and rain will cease too, until more air, from a greater distance, that has not been deprived of its vapor, flows in and ascends. Then cloud will again begin to form, and the violence and rapidity of the outflowing of the air above will be increased by the evolution of the caloric of elasticity — the barometer will rise rapidly in the annulus, and fall in the central part of the ascending column; and these alternations may continue while the volcano is in activity, more particularly if the violence of the volcano itself should be increased periodically.

As air cannot move upwards without coming under diminished pressure, and as it must thus expand and grow cooler, and consequently form cloud, any cause which produces an up-moving column of air, whether that cause be natural or artificial, will produce rain, when the complement of the dew point is small, the air calm below and above, and the upper part of the atmosphere of its ordinary temperature.[1]

Volcanoes, therefore, under favorable circumstances, will produce rain; sea breezes, which blow inwards every day towards the centre of islands, especially if these islands have in them high mountains,[2] which will prevent anyupper current of air from

[1] The relative temperature of the upper air may be known by a series of observations with Pouillet's actinometer. (See art. 170.)

[2] Clinton Hotel, New York, Dec. 20, 1839.

To Professor Espy:

Dear Sir,—Understanding you are desirous of collecting curious meteorological facts, I take the liberty of communicating to you what I saw in the month of December, 1815, at the island of Owyhee. I lay at that island in the Cavrico bay, in which Capt. Cook was killed, three weeks, and every day during that time, very soon after the sea breeze set in, say about 9 o'clock, a bending the upmoving current of air out of the perpendicular, before it rises high enough to form cloud, such as Jamaica, will produce rain every day ; great cities where very much fuel is burnt, in countries where the complement of the dew point is small, such as Manchester and Liverpool, will frequently produce rain ; even battles, and accidental fires, if they occur under favorable circumstances, may sometimes be followed by rain. (Sect. X., *passim.*) Let all these favorable circumstances be watched for in time of drought (and they can only occur then), and let the experiment be tried ; if it should be successful, the result would be highly beneficial to mankind. It might probably prevent the occurrence of those destructive tornadoes which produce such devastation in the United States ; for if rains should be produced at regular intervals, of no great duration, the steam power in the air might thus be prevented from rising high enough to produce any storm of destructive character. Besides its utility to the farmer, it would be highly useful to the mariner in the following way : As the very time and place of the commencement of the rain would be known, it would be easy to find out in what direction, from the place of beginning, it moved along the surface of the earth, and also its velocity of motion, and the shape that it assumed from time to time in its progress ; and this knowledge being extended to the motion of storms on the ocean, will enable the mariner, who has the power of locomotion, to direct his vessel so, when

cloud began to form round the lofty conical mountain in that island, in the form of a ring, as the wooden horizon surrounds the terrestrial artificial globe, and it soon began to rain in torrents, and continued through the day. In the evening the sea breeze died away and the rain ceased, and the cloud soon disappeared, and it remained entirely clear till after the sea breeze set in next morning. The land breeze prevailed during the night, and was so cool as to render fires pleasant to the natives, which I observed they constantly kindled in the evening. I was particularly struck with the phenomena of the cloud surrounding the mountain, when none was ever seen in any other part of the sky, and none there till after the sea breeze set in, in the morning, which it did with wonderful regularity. The mountain stood in bold relief, and its top could always be seen from where the ship lay, above the cloud, even when it was the densest and blackest, with the lightning flashing and the thunder rolling, as it did every day. I passed up through the cloud once, and I know, therefore, how violently it rains, especially at the lower side of the cloud. This rain never extends beyond the base of the mountain ; and all round the horizon there is eternally a cloudless sky. The dews, however, are very heavy, and there seems to be no suffering for want of rain. That this state of things continues all the year, I have no doubt, from what an American, by name Sears, who had spent four years there, told me ; he said he had seen no change in regard to the rain. CALEB WILLIAMS,
Of Providence, Rhode Island.

JANUARY 2d, 1840. Having read the above, I can safely attest to the truth of what Mr. Caleb Williams writes ; but, furthermore, can say it is the same on all the mountains on the different islands of the group.
JOSEPH STEELE, *of Boston.*

one of these great storms comes near him, that he can use as much wind in the borders of the storm as will suit the purposes of navigation — for heaven undoubtedly makes the wind blow for his use, and not for his destruction, provided he becomes acquainted with the laws which govern its motions. From the preceding principles, he will be able to know in what direction a great storm is raging, when it is yet several hundred miles from him, for the direction of the wind alone points it out. If, however, the storm should be of such great length, moving side foremost, that it will preclude the possibility of avoiding it, he will at least be enabled to know in what direction to steer his ship, to get out of the storm as soon as possible. For example, if it shall be found that storms between the United States and Europe always move towards the east, then it will manifestly be improper to scud with the wind in the latter part of the gale, when the wind is blowing from the westward, because this would be to keep in the storm as long as possible. (134, 170.) The sailor also will be able to know when he is out of danger; for when a great storm has passed off to the east in middle and high latitudes, and to the north in low latitudes, on the north of the equator, he will know that it never returns; and therefore he will not be afraid to spread his sails to the wind, before the calm of the annulus comes upon him. The mariner will finally be able, by observing storm clouds on their approach, to ascertain the direction in which storms move, for these storm clouds frequently exhibit their front edge above the horizon in the form of an arch; and if the highest part of the arch approaches towards the zenith, then is the storm coming from the point where the arch first appeared.

When a storm has a much greater diameter from north to south than from east to west, the wind will not blow towards a central point, but towards a central line, which may be called the transverse diameter of the storm.

On the northern end of the storm, if it moves towards the east, the wind will change round without a lull, by north towards the west; and on the southern end of the storm the wind will change round without a lull, by south towards the west; but in the middle of the storm the wind will change with a lull from easterly to westerly. (136, 171, *et passim.*)

When the storm is of great length, north and south, the lull in the central parts may be experienced simultaneously, at considerable distances apart, north and south, which could not be the case if the storm was round; and as this occurs frequently on the coast of the United States, it is certain, from that circumstance alone, that the centre of storms is frequently a line of great length; and moreover, as the wind in the first part of the storm is frequently south east, and in the last part of the storm north west; and as the barometer falls successively from north of west to south of east,[1] it seems highly probably that these storms of oblong form move towards the south of east *(passim.*[2]*)*

In the West Indies, from Barbadoes to Jamaica, it is known, by the invaluable labors of Redfield and Reid, that the hurricanes

[1] See diagram at the end of Appendix, pp. 550 and 551.

[2] It seems probable, from the following facts, extracted from Orlando Whistlecraft's Climate of England, that thunder storms in England also travel from north of west to south of east.

Page 2. In summer, too, a south east wind always prevails in the eastern countries before the great thunder storms, which by night spread themselves over the greatest part of England. These storms are evidently aided in their rise and progress, or passage to the eastward, by a south west or west wind behind them, which combats against the sea breezes so usual in Kent, Essex, Suffolk, &c., from south east or east during hot days.

Page 7. The south east wind blows in July with the hottest and clearest days for nearly a week in the eastern counties, until vapors arise with a south west current and form distant ranges of rocky clouds in the south west horizon. These and the white and round detachments of cirrocumulus in trains across the zenith, are the first clouds after clear and hot days indicating a change, which takes place by the south western clouds coming on with a severe thunder storm by night for many hours, while the wind continues east or south east, until it passes, when it veers to the south west, whence the storm arose.

Page 10. On the night of the 9th August, 1787, a dreadful thunder storm came on. This was introduced by a fine and hot week, with easterly wind, and the storm came on as usual from south west, whither the wind afterwards veered.

Page 22. In a hot and clear sunshine, so much moisture is drawn up by evaporation, that many distinct cumuli are formed by 10, A. M. in the otherwise clear sky. These increase in size till about 2, P. M., after which they decrease, and at sunset we have none again in view.

Page 27. The cumulus is truly the day-cloud, beginning to form itself in a previously clear morning, increasing till 2, P. M., and then decreasing, until at sunset no cloud again appears. In this case we see a mere speck of vapor, at about 10, A. M. in a summer's day, accumulating till a semicircular body is formed, having a flat base, while the upper part is somewhat rocky in appearance.

Page 28. As the cumulus is about to pass into the nimbus, the middle of the cloud will represent the neck of a mushroom, and the summit spreads and overhangs the base in a most striking manner, and the tops of these clouds may be compared to the ebullition or at least to the effervescing of some fluid.

Page 30. It has been long observed by meteorologists, that a south east wind (in the eastern counties at least,) precedes the most violent thunder storms, and that the storm itself works its way in a higher current from the westward.

Page 67. On the 23d May, 1830, an extraordinary cloud began to rise at 6, P. M., and veiled the south west in blackest hue for two hours. It made its way against the opposing current below with a continued blaze of blue lightning, and continued over us about an hour.

And on the 3d of June, at 4, P. M., a violent storm came up against the lower current, which was east north east.

On 26th June, 1833, a thunder storm came from south west, wind north east. The same phenomenon occurred on the 24th August, 1834, and also on the 13th October, 1836, and 29th June, 1838.

there move from the south east to north west; therefore if the wind springs up violent from north west in those parts, the mariner may be sure that a hurricane is coming upon him if he remains stationary; and if it springs up in any other direction, he will know in what direction to sail to avoid its violence.

This paper gave rise to a very interesting conversation, but from the great length of the paper itself, we can only direct attention to the leading points of the discussion. Professor Stevelly called the attention of the Section to the fact that he had, at the Edinburgh meeting in 1834, used the principle of cold, produced by rarefaction, to explain what he called the secondary formation of clouds, and thus the propagation of storms; and even assigned this rarefaction as the cause of summer hail, (see *Athen.* No. 361, 1834).

He objected to the main position, however, in Mr. Espy's theory, that *the fall of temperature* caused by the expansion of any body of air rendered light, by being loaded with moisture as it rose in the atmosphere, was the same as the *constituent temperature of the strata of air* into which it rose, that is, of equal tension. He deduced from the numbers given by Poisson, that it was much greater; that a cloud would be colder and not hotter than the surrounding air, and therefore the violent ascending vortex calculated upon by Mr. Espy, would not exist.

Professor Forbes had three objections to Mr. Espy's theory, 1st, the small funnel at the centre of a tornado, through which Mr. Espy supposed the air to rise, would be insufficient to vent all the air which would rush, during a tornado, with the frightful velocity we know it to attain, through the constantly enlarging rings surrounding that central funnel, to an extent of many hundred miles: 2d, as the tornado had a progressive motion, as Mr. Espy admitted, it would be more difficult than Mr. Espy supposed to deduce from the way in which the trees in its path were thrown, the actual course of the atmospheric particles at any instant, as each would move with a motion compounded of two motions, both varying in relative direction and magnitude: 3d, he thought that all the vapor in the air would be condensed into cloud much sooner than Mr. Espy supposed, and he thought it certain that the small amount of heat given out by the vapor would not suffice to expand the air in the funnel to the extent required, if Mr. Espy's views were correct.

To the first objection Mr. Espy replied, that the objection was answered in the paper itself; in which it was shown that the air was calm all round the tornado, within a few hundred yards, and that it ought to be so on his principles.

To the second he answered, that Mr. Redfield had laid down a test, by which it could be ascertained with absolute certainty whether or not the air blew in towards the centre, and that was, that the trees, in the central line of the path, should be found lying parallel with the path ; and he stated that this had been found to be the case in all the tornadoes which had been examined.

To the third he answered, that if all the vapor should be condensed as Professor Forbes thinks, then the effects produced would be much more violent. Professor Forbes would find, that if *all* the vapor which is in a mass of air when the dew point is 73°, (and it is sometimes higher than that when tornadoes occur,) should be condensed, the latent caloric given out would heat the air more than 70° ; and in case of hail, nearly 80°, by the addition of the caloric of fluidity. Professor Forbes would find, by a rigid examination of the subject, that all the vapor is never condensed, because the dew point, at great heights, falls by expansion faster than the temperature.

As to the question whether Mr. Redfield and Colonel Reid's theory of a whirl, or Mr. Espy's radial theory, was most accordant with fact, Mr. Osler said, that from the investigation he had given this subject, he was convinced that the centripetal action described by Mr. Espy took place in most hurricanes. The particulars, he, Mr. Osler, had collected, together with the indications obtained from the anemometers at Birmingham and Plymouth, satisfied him that the action of the great storm of the 6th and 7th of January, 1839, was not rotatory at the surface of the earth when it passed across England. He differed, however, both from Mr. Espy and Mr. Redfield in one essential point, for he believed it would be almost impossible to have a violent hurricane, without, at the same time, having both rotatory and centripetal action. A storm might very probably be generated in the first instance, in the manner accounted for by Mr. Espy, or by the action of contrary currents ; in the first case, the rush of air towards a spot of greater or less diameter, would not be perfectly uniform, owing to the varying state of the surrounding atmosphere ; this, together with the upward tendency of the current, would, in some cases, produce a violent eddy or rotatory motion, and a whirlwind of a diameter varying with the cause would ensue ; the centripetal action would thus be immensely increased, the *whirlwind itself* demanding a vast supply of air, which would be constantly thrown off spirally upwards, and diffused over the upper atmosphere, thus causing the high state of the barometer which surrounds a storm. He further stated, that he had brought his theory of the combined action of centripetal and rotatory motion before the meeting of this Association at Birmingham, and a short notice of it would be found in the reports of the Sections. If no rotatory action takes place, he believed that we merely experienced the rush of air which necessarily precedes a heavy fall of rain or thunder storm, but he believed that nothing violent enough to be called a hurricane could take place, unless a violent rotatory or whirling action be first produced, and that in many, and perhaps most cases, the rotatory portion is not in contact with the earth.

Mr. Arch Smith said, there was one point which must not be overlooked in any correct comparison of the rival theories. From the principle of the conservation of areas it was perfectly certain, that if a storm was caused in the manner supposed by Mr. Espy, there must be a rotation, greater or less, in the centre. Because, unless the motion of all the currents was accurately directed to one point, or at least their *moments* in a horizontal plane were equal to zero, which was infinitely improbable, a motion of rotation must be the result, as in the instance of the motion of water in a funnel, cited by Mr. Espy.[1] If the central space of comparative rest were large, the whirl might be imperceptible; but if small, as in the case of a water-spout, it must be considerable. Without embracing either theory, he thought it difficult to conceive, as he understood Mr. Osler to do, the motion of rotation to be the primary, and the centripetal (which indeed would be centrifugal) force to be the secondary phenomenon. But it was comparatively easy to suppose the centripetal motion to be the primary phenomenon, and quite certain that if so, there must result a secondary phenomenon of rotation, of which indeed some indications appeared in Mr. Espy's maps.

In making some remarks on the preceding paper, Sir David Brewster observed, that it was impossible to form any decided opinion on the subject, from the great want of well ascertained facts; and as Mr. Espy had founded his theory expressly on observations, often made by himself, it was impossible to do justice to his ingenious views until a greater number of facts had been collected. The facts, too, stated by Mr. Espy, were opposed to those observed by others. In the case of hurricanes or tornadoes, the convergency of the aerial currents in the one theory, and their rotatory motion in the other, were not *observed*, but *inferred* from a number of facts; but as Mr. Espy regarded water-spouts as formed in the same manner as tornadoes,

[1] Mr. Espy's experiments with a funnel, are in opposition to the statement made here. He has performed many, and in all instances where care was taken to have the water still, before removing the finger from the lower end, and letting the water run out, it discharged the whole contents without any whirling motion. The same occurred, whether a funnel was used, or a tub with a hole in the bottom. Mr. Espy acknowledges, however, Mr. Smith's doctrine of the conservation of areas to be correct, and he admits it as highly probable, that spouts sometimes whirl one way, and sometimes another; but generally neither way; and in all cases, the whirl, if any, would only be perceptible very near the centre. He first supposed that all spouts whirled, and was only compelled to abandon this notion by the facts themselves.

and as Col. Reid had distinctly stated in his letter to Sir David, already referred to, that he had *actually seen*, from the government house at Bermuda, by means of a telescope, the *water-spout revolving like the hands on the dial plate of a watch*, there could be no doubt that we were at variance about facts. This explicit and distinct *observation* of a rotatory motion by so able and accurate an observer as Col. Reid, was worth a thousand inferences. As to Sir David Brewster's objection, Mr. Espy thought his paper itself contained an answer to it, where he showed that bodies taken up on one side of the tornado, would whirl one way, and bodies taken up on the other side, would whirl the other. And it was worthy of notice, that all Col. Reid's spouts whirl from left to right, and all Mr. Redfield's from right to left, on this side of the equator. Mr. Espy had examined a great many witnesses of the Brunswick tornado, and some saw the materials which went up, whirl one way, and some another, though they were standing together ; and Professor Strong and Professor Beck of New Brunswick, saw the materials whirl as the hands of a watch, contrary to the manner Mr. Redfield says this and all other spouts in this latitude, whirl. Professor Phillips must say that he thought the statements of fact connected with tornadoes, as stated in the American journals, were more consistent with Mr. Espy's than with Mr. Redfield's theory ; and Col. Reid thinking he saw rotation in a water-spout could not invalidate the abiding evidence from uprooted forests.

Report of the Academy of Sciences, (Paris), on the labors of J. P. Espy, *concerning Tornadoes, &c.*

Committee, Messrs. Arago, Pouillet, Babinet reporter.

Messrs. Arago, Pouillet, and myself, have been appointed by the Academy to make a report to it upon the observations and theory of Mr. Espy, which have for their object the aerial meteors known by the names of storms, water-spouts and tornadoes, which cause so much destruction on land and sea in the vicinity of the Gulf of Mexico. These storms are produced in the same manner in every part of the globe, when a few given circumstances concur in one place.

The labors of Mr. Espy have already considerably occupied the attention of the learned world, and may be considered under three different points of view. First, the facts which he has recognised and substantiated, and the proofs which support them ; second, the physical theory, by which he explains them and the conclusions which he deduces from that theory ; third, the observations which are yet to be made according to this theory, based upon facts, and the practical rules which the mariner, the farmer, and the meteorologist will obtain from it; the two former for their own benefit, the latter for science, which is useful to all.

The facts which result from the numerous documents which Mr. Espy has placed in the hands of the committee, are the following: the motion of the air in the meteor under consideration, called tornado or water-spout, if it is violent, and of small extent; a storm, if it covers many degrees of the earth's surface; the motion of the air, we say, is always convergent, either towards a single centre, when the tornado has a circular form, and limited extent, or towards a diametrical line, when the tornado or storm is of a lengthened form and extends over many hundred leagues.

If the tornado is very small, in which case the violence of the motion of the air is greater, a cloud is frequently seen in the centre, whose point descends more and more until it touches the earth or sea. Water-spouts are small tornadoes, and the force of these meteors in the south and east of the United States is such, that trees are carried up in the air, and the heaviest objects are overturned, displaced, and transported. Finally, we have only to call to mind the well known storms of the Antilles, which change even the form of the ground over which they pass. We will adopt the technical word tornado to designate the meteor in question, whatever may be its extent or violence. China and the neighboring seas, Central Africa and the south west part of the Indian Ocean, are, like the West Indies, the theatre of meteors of the same nature, and not less disastrous.

In observing at the same moment the force and direction of the wind, which is shown by the overturned trees, the displaced movable objects, in a word, by the traces impressed upon the soil, Mr. Espy proves that in the same instant the motion of all parts of the air which is reached by the tornado is tending towards a central space, point or line, so that if the wind on one side of the meteor blows towards the east, it blows with the same violence towards the west on the other side of the tornado, and frequently at a very short distance from the first place, whilst in the centre, an ascending current is formed of astonishing rapidity, which, after having risen to a prodigious height, spreads out on every side to a certain limit, which we shall soon determine by the observations of the barometer. This ascending current loses its transparency at a certain height, and becomes a true cloud of the kind called cumulus, the base of which is horizontal, and whose height is determined by the temperature and humidity of the atmosphere. The central cloud of the tornado is constantly reproduced, in proportion as it is carried off by the rapid current of the centre; and, according to Mr. Espy, when rain or hail proceeds from this meteor, which is generally the case, it is the cold, caused by the expansion of the air carried into the higher regions of the atmosphere, which condenses the water. Electricity, when it appears in the tornado, is not, according to Mr. Espy, essential to the phenomenon.

The existence of an ascending current of extreme violence once placed beyond doubt by the phenomena of the rising of the air, and its motion towards a centre or towards the great diameter of the oblong space occupied by the tornado, being well established by facts, Mr. Espy examines the progressive movement of the whole meteor, which is very slow, compared with the velocity of the wind in the mass of air which becomes at each instant a part of the tornado. Mr. Espy shows that near the latitude of Philadelphia, where cirrus clouds, very elevated as is known, move towards the east, the centre of the tornado moves almost always towards the east, as well as in Europe, where the west wind is predominant; whilst, in the inter-tropical regions, (Barbadoes, Jamaica, the north of the Indian Ocean,) the meteor moves towards the west or north west, following the course of the trade winds. These assertions are also verified with regard to China and the Indian Ocean, according to the maps of Berghous. The barometer, in the centre of the meteor, is sometimes nearly 2.25 of an inch (sixty millimetres,) lower than towards its border, and its limit is marked on all its outline by a closed curve, along which the barometer is found to be at its " normale " height, whilst, on the other side of this line, further from the centre, the barometer is observed to rise, which rise in small tornadoes is .08 of an inch, (two millimetres,) but which may be forty or forty-eight hundredths of an inch, (ten or twelve millimetres) in very extended storms. If the centre of the tornado moves, (which may take place in any direction, when compared with the diametrical line,) and the effects produced by the motion are examined, it is always found that if the meteor has followed in its motion the line of its greatest diameter, the tree which fell the first, indicates a point anterior in the path of the meteor, and the tree which fell last, a posterior point. Thus it is constantly found that the trees which were overthrown with their tops turned towards positions anterior to the centre of the tornado, are covered by trees falling in the direction of the centre at a posterior period. In short, in this same case, the branches of the trees not overthrown, growing on the side farthest from the opposite side of the line which the centre of the meteor takes, have followed the wind and are twisted around the trunk of the trees.

The circumstances favorable to the sudden production of a tornado, large or small, are, according to Mr. Espy, a warm and humid atmosphere, covering a country sufficiently level and extended, still enough to allow that part of the air which is accidentally the least dense, to rise to a great perpendicular height above the middle of the heated space which is charged with transparent vapor; moreover, in the higher regions, a cold and dry air, whose situation and especially whose density contrasts with that of the ascending current which dilates, cools, loses its transparency by the precipitation of its dampness, keeping notwithstanding a specific gravity less than that of the air which surrounds it, and by its expansion, presenting the form of a mushroom or the head of a pine with or without the prolongation or appendage towards the base, which appendage, cloudy and opaque, shows a space where the expansion and the cold are at their maximum, and where, consequently, the precipitation of vapor commences almost immediately above the ground or the surface of the sea.

Such are then the principal points which Mr. Espy has obtained from numerous observations. The motion of the air towards the centre of the meteor, the depression of the barometer in the centre, the central ascending current, the formation of cloud at a certain height, and its circular expansion after this cloud has attained a prodigious height, an expansion accompanied with rain and hail, and finally, the motion of the whole meteor, *en masse;* these, I say, are the points which the extensive labors of Mr. Espy, his own observations, and the documents which he has collected, and which he intends publishing immediately in a special work, have placed beyond doubt, and which seem even to have triumphed over every objection, and to have rallied all opinions to his own.

Let us now see the theory upon which he bases his observations, or rather which is based upon these facts well observed, well proven, and always reproduced in nature with similar circumstances.

Mr. Espy thinks that if a very extended stratum of warm and humid air at rest, covers the surface of a region of land or sea, and that by any cause whatever, for example a less local density, an ascending current is formed in this mass of humid air, the ascending force, instead of diminishing in consequence of the elevation of the rising column, will increase with the height of the column, exactly as though a current of hydrogen was rising through the common air, which current would be pushed towards the top of the atmosphere, with a force and velocity in proportion to its height. This column of heated air may also be compared to that in chimneys and stove-pipes, of which the draught is in proportion to the height of the pipe containing the warm air. What then is the cause which renders the warm and humid ascending current, lighter in each of its parts, than the air which is found at the same height with these different portions of the ascending column?

This cause, according to the *sufficiently exact* calculations [*tres suffisament exact*] of Mr. Espy, is the constantly higher temperature which the ascending column retains, and which proceeds from the heat furnished by the partial condensation of the vapor mixed with the air, making this ascending column a true column of heated air, that is to say, of a lighter gas; for the weight of the water which passes into the liquid state, is far from compensating the excess of levity which proceeds from the more elevated temperature which the air preserves. (This weight only equals one fifth of the diminution of the weight in ordinary circumstances.)

Thus, the higher the column is, the greater is the ascending force, and the rushing in of the surrounding air on all sides will be produced with more energy. To understand this effect better, let us consider a mass of warm and dry air rising in the midst of a colder atmosphere. In proportion as this air rises, it will expand, because of the less pressure which it will experience, and consequently become colder; it will arrive then quickly at an equilibrium both of temperature and pressure with a layer more or less elevated, which it will soon reach, and in which it will remain; but if this only cause of cold, expansion, is overbalanced by a cause of heat, for example the heat furnished by the vapor which is condensing, this air will remain constantly warmer than would have been necessary to attain the same temperature and pressure as the surrounding air. It will then be constantly lighter, and the higher the column, the greater the ascending force.

The calculations of Mr. Espy show, without the slightest doubt, that the column of damp air regaining in temperature, by the condensing of the vapor, a part of the heat lost by expansion; this column always remains warmer than the air which is at the same height with each of its parts. Finally, Mr. Espy furnishes the exact data which are still wanting to science, by the experiments made upon the temperature which the air preserves by the effect of condensation of the vapor in a closed vessel which he calls a "nephelescope," and in which he compares the thermometrical fall produced in the air by a diminution of superincumbent pressure, to what takes place in nature, whether operating on dry, or employing damp, air. Notwithstanding the influence of the sides of the vessel, every time a light cloud is formed in the apparatus, the temperature undergoes a much less reduction than that which takes place when the point of precipitation of vapor has not been attained, or when the experiment is tried on dry air.

The theory of Mr. Espy also accounts very well for the formation of a true cloud analogous to the cumulus with horizontal base, from the moment when the warm and damp air has acquired such an expansion, that the cold produced by it will cause a precipitation of water, and the base of the central cloud of the tornado, if it is horizontal, as is the case in the great meteors of this nature, should be lowered in proportion as the moist air which is carried up is more fully charged with vapor; this base, like that of the cumulus, being of necessity found at the point where the temperature of the ascending current becomes that of the *dew point*, which itself depends evidently upon the degree of dampness of the air. This theory further explains how, in the small tornadoes, whose violence is remarkable, an expansion takes place in the centre of the meteor, at a very small height, sufficient to condense vapor by the cold and consequently to produce this kind of appendage which particularly distinguishes small tornadoes, or common water spouts. Let us add that the calculations of Mr. Espy, upon the density of the warm column, its comparative levity, the ascending force of the current, the central depression which is the consequence of it, the rapidity with which the surrounding air rushes towards the place where the pressure is diminished, finally all the conclusions drawn from the physical data of the phenomena have been proved and ascertained with sufficient exactness to leave no doubt as to this portion of Mr. Espy's theory.

One word remains to be said relative to the progressive movement of the meteor. This movement may depend upon an ordinary wind, which, imparting a common motion to the whole atmosphere, would not disturb the ascension of the column of moist air. But as these phenomena are produced suddenly in the midst of a great calm, Mr. Espy thinks that, in accordance with observed facts, the motion of the meteor should be attributed to the winds, which predominate in the upper part of the atmosphere, and that in modern latitudes, this motion should thus take place towards the east, whilst in the equatorial regions this motion should be directed towards the west, as the current of the trade winds. In a word, the slight surcharge which is owing to the spreading out of the air, around the top of the meteor, accounts for the trifling elevation of the barometer, which the invasion of the tornado, in every place presents, and can even, according to Mr. Espy, serve as a prognostic of it.[1] Another result is, that beyond the limits of the meteor, a feeble wind ought to be observed, as is the case, whose direction is opposite to that of the air which is violently rushing towards the centre of the tornado.

The consequences which Mr. Espy deduces from this theory, are, that in many localities, in Jamaica, for example, the sea breezes cause a motion of the air perfectly analogous to that which constitutes a tornado, and that the results of it are the same, namely, rain and tempest at stated hours, on each day of summer. The same circumstances produce the same effects in other well known localities, volcanic eruptions, great conflagrations of forests, with the favorable circumstances of tranquillity, heat, and moisture, ought also to produce ascending currents and rain. In the midst of all the theoretical deductions of Mr. Espy, it should be remark-

[1] The reader will recollect that in the "Report," *tornado* is used to signify both large and small storms.

ed, that a descending current of air never can communicate cold, for this current would become warm by compression in proportion as it should descend, and the meteorological temperature of many places sheltered from the ascending winds, is considerably augmented by this cause. The tempests of sand in many parts of Africa and Asia, although possessing much less violence, owing to the dryness of the heated air, accord perfectly with the theory of Mr. Espy, both as to quantity and the nature of their effects.

Lastly, let us observe, that if, in tornadoes, the air is absorbed by the lower portion of the column, and not by the higher parts, it is, that the difference between the pressure of the heated column, and that of the surrounding air, is much more marked, as it is considered lower down, in the column of less density and equal elasticity, so that, in the case of an equilibrium, at the lowest point this difference would be precisely the total difference of the whole heated column to the whole column of air of the same height situated around the first. The observations and experiments which have been suggested to Mr. Espy by the study of the phenomena of tornadoes, and the theory he has given of them merit the most serious attention. It is very evident that science would be much benefited by the establishment of a system of simultaneous observations of the barometer, thermometer, hygrometer, and especially of the anemometer, if at least they could be procured capable of giving with sufficient accuracy the intensity of the wind at the same time with its direction and the time of each variation of force. The influence which electricity exerts in this phenomenon, remains yet to be determined. Mr. Espy thinks that artificial causes, for example, great fires kindled in favorable circumstances of heat, of tranquillity, and humidity, can cause an ascending column of much less violence, the useful results of which would be on the one hand rain, and on the other the happy prevention of disastrous storms. It will be necessary to see in Mr. Espy's work itself, the further beneficial results to navigation from the views furnished by his theory.

The different manners in which philosophers, by means of apparatus whose principle of action is the centrifugal force, have imitated water-spouts or small tornadoes, do not appear to us reconcilable with Mr. Espy's theory, which, based upon facts, equally refutes the idea of a whirling motion of the air in the tornado.[1]

[1] Philosophical Magazine, for June, 1841. Sir David Brewster says, "the theory of the rotatory character of storms was first suggested by Col. Capper, but we must claim for Mr. Redfield the greater honor of having fully investigated the subject, and apparently established the theory upon an impregnable basis."

Here we should compare the theory of Mr. Espy with other theories, anterior or contemporaneous. The labors of Franklin, and of Messrs. Redfield, Reid, and Peltier would furnish as many excellent observations and parts, or the whole of the phenomena, very well studied. But the extensive discussion which we should have to establish before deciding in favor of Mr. Espy, would lead us too far. Mr. Espy himself, as to the electrical part of the phenomenon, which, however, he regards as only accessory and secondary, acknowledges that his theory is less advanced and less complete than it is with regard to the phenomena of the motion and precipitation of the water, which are, according to him, the base of the production of the meteor.

Finally, it is proved by the investigations of Mr. Espy, that it will be impossible hereafter to adduce in the mean [normale] state of the atmosphere, a descending current of air as a cause of cold, or an ascending current of dry air, a cause of heat. The applications of this theory present themselves in "climatology," but this principle especially discards the idea of explanation of the tornado by the centrifugal force, which would then cause the upper air to descend in the centre of the tornado, which air becoming heated by the augmented pressure, could not allow its own vapor to be precipitated nor precipitate that of the air with which it came in contact.

CONCLUSION.

In conclusion, Mr. Espy's communication contains a great number of well-observed and well-described facts. His theory, in the present state of science, alone accounts for the phenomena, and, when completed, as Mr. Espy intends, by the study of the action of electricity when it intervenes, will leave nothing to be desired. In a word, for physical geography, agriculture, navigation, and meteorology, it gives us new explanations, indications useful for ulterior researches, and redresses many accredited errors.

The committee expresses then, the wish that Mr. Espy should be placed by the government of the United States in a position to continue his important investigations, and to complete his theory, already so remarkable, by means of all the observations and all experiments which the deductions even of his theory may suggest to him, in a vast country, where enlightened men are not wanting to science, and which is besides, as it were, the home of these fearful meteors.

The work of Mr. Espy causes us to feel the necessity of undertaking a retrospective examination of the numerous documents already collected in Europe, to arrange them and draw from them deductions which they can furnish, and more especially at the present period, when the diluvial rains, which have ravaged the south east of France, have directed attention to all the possible causes of similar phenomena. Consequently, the committee proposes to the Academy to give its approbation to the labors of Mr. Espy, and to solicit him to continue his researches, and especially to try to ascertain the influence which electricity exerts in these great phenomena, of which a complete theory will be one of the most precious acquisitions of modern science.

The conclusions of this report are adopted.

NOTE.

I have stated in the Synopsis, that islands, with high mountains in them, are more likely to have rains from sea breezes, than those without mountains. The following facts go to confirm that position, and they will be easily understood from the theory, without further explanation. Certainly they are not to be explained by any supposed attraction of mountains for clouds, as is asserted by the author of the American Almanack, and by many higher authorities. The facts, indeed, which Mr. Borden gives, prove that the cloud is not attracted to the mountain, but formed there.

Dr. Campbell, of Lancaster, England, observes, " that the influence of hills, in attracting clouds, is nowhere more conspicuous than at Kendall ; that one third more rain falls at Kendall than at Lancaster, a distance of only twenty miles, and that it is by no means unusual to see from the church yard at Lancaster, the hills about Kendall enveloped in thick clouds, while the sky at the Lancaster side of Farlton Knott appears perfectly clear. And Dr. Garnett says, the summer of 1792 was remarkably dry in Yorkshire, and all the eastern side of the English Appennine was burnt up for want of rain ; while, on the western, they had plenty of rain and abundant grass." [Transac. of Royal Irish Acad., vol. xvii. p. 224.

" That the mist should remain so nearly stationary on the top of Table Hill, while the south east wind continues, is not surprising, considering the height of the hill, 3582 feet above the level of the sea, its precipitous sides, and the extensive surface of its top ; nor is it strange that it should rarely descend, except when the wind blows hard, taking into account the situation of the ground beneath, sheltered and warm, and the site of a large town, from which a current of hot air must constantly be rising." [Mr. John Davy. Tilloch's Magazine, vol. li. p. 35.

" The air on the summit, which rises to the height of 3582 feet above the level of Table Bay, in the clear weather of winter, and in the shade, is generally about fifteen degrees of Fahrenheit's scale lower than in Cape Town. In the summer season the difference is much greater, when that well known appearance of the fleecy cloud, not inaptly called the table cloth, envelopes the summit of the mountain. In the heat of the summer season, when the south east monsoon blows strong at sea, the water taken up by evaporation is borne in the air to the continental mountains, where, being condensed, it rests on their summits in the form of a thick cloud. This cloud, and a low dense bank of fog on the sea, are the precursors of a similar but lighter fleece on the Table Mountain, and of a strong gale of wind in Cape Town from the south east. These effects may be thus accounted for : The condensed air on the summit of the mountains of the continent, rushes, by its superior gravity, towards the more rarefied atmosphere over the isthmus, and the vapor it contains is there taken up and held invisible, or in transparent solution. From hence it is carried by the south east winds towards the Table and its neighboring mountains, where, by condensation from decreased temperature and concussion, the air is no longer capable of holding the vapor with which it was loaded, but is obliged to let it go. The atmosphere on the summit of the mountain becomes turbid, the cloud is shortly formed, and, hurried by the wind over the verge of the precipice in large fleecy volumes, rolls down the steep sides towards the plain, threatening momentarily to deluge the town. No sooner, however, does it arrive in its descent at the point of temperature equal to that of the atmosphere in which it has floated over the isthmus, than it is once more taken up, and 'vanishes into air — to thin air.' " [John Barton. Tilloch, vol. x. p. 225.

The doctrine of concussion producing condensation of aqueous vapor, has no foundation in nature. It is surprising to me, that Mr. Barton should not have known the principle, that cold, by the expansion of the air as it ascends the sides of mountains, is sufficient to produce condensation. It is a principle long familiar to the scientific world, and it is one which I used in my early writings, as belonging to the great storehouse of science, as common property, without even inquiring who was the original discoverer, or who first saw a cloud form in the receiver of an air pump on extracting the air. Mr. H. Meikle claims this discovery as original. So far as I am concerned, he shall never be deprived of that honor; I lay no claim to it. (See Appendix, page 547.)

Facts communicated by Simeon Borden, Esq., of Boston. "In the western part of the state of Massachusetts, there are many mountains of considerable elevation. Amongst them I have spent much time in the course of three or four years just past. The following phenomena are of almost every day occurrence:

"One day, as I was standing near the base of the Watatick mountain, (a mountain about two thousand feet in height,) looking at the clouds, which were apparently resting upon its top at that time, — the wind was blowing briskly from some southerly point; the day was remarkably pleasant, the sun shone brilliantly, and the cloud which capt the mountain was not large, — I observed frequently, upon the windward side of the mountain's top, that many square yards of transparent atmosphere would occasionally become suddenly transformed into a dense fog or cloud, which would then pass with the current of the atmosphere across the top of the mountain, and would then as suddenly vanish into transparent atmosphere again, resembling in its transformation, very much in form or shape, that of *a vanishing flame of fire.* I noticed at other times, that although the wind would frequently be blowing briskly, still the cloud would apparently remain stationary upon the mountain top; sometimes it would however appear to enlarge, and then again would diminish, and pretty uniformly in fair weather would rise from and leave the mountain top entirely near midday."

PHILOSOPHY OF STORMS.

SECTION FIRST.

THEORY DEDUCED FROM PHYSICAL LAWS.

1. The experiments of the illustrious Dalton and Gay-Lussac have shown that when the dew point is 80° Fahrenheit, and the barometer 30 inches, the quantity of vapor in atmospheric air is one forty-eighth of the whole weight and one thirtieth of the whole bulk; when the dew point is 71°, the quantity is one-fourth less; and when the dew point is 59°, the quantity of vapor is only one half as much as when it is 80°; and at 39°, the quantity would be reduced to one quarter, &c.

2. It is well known by observation that the temperature of the atmosphere falls about one degree for every hundred yards above the level of the ocean, in temperate latitudes, at a mean, in the summer season, and a little less, perhaps, in winter: and in the torrid zone at all seasons, it is probable this quantity is near the truth. This rule extends to the height of seventy or eighty hundred yards at least.

3. It is known by direct experiment and also indirectly

by the velocity of sound, that when air is expanded by diminished pressure, it becomes colder at a rate not differing very widely from that which obtains in the atmosphere; so that if dry air were to ascend in the atmosphere, it would, by expansion, cool down about one degree for every hundred yards of its ascent; or perhaps a little more.

4. It has been shown by many experimenters, particularly by Berard and Delaroche, and also by Clement and Desormes, that the specific caloric of atmospheric air under a mean pressure, is about one quarter, that of water being one.

5. It is also known that the latent caloric of the vapor of water at zero, is 1212° Fahrenheit, and that as the temperature of the vapor increases, the latent caloric diminishes in the same proportion, so that the latent and sensible caloric of vapor, when added together, will always make 1212°.

6. It is known also that the caloric of liquidity of water is 140° Fahrenheit; or that water, on freezing, gives out 140° of caloric.

7. As the specific gravity of steam or vapor is about $\frac{625}{1000}$ of that of the air at the same temperature, if a portion of air near the earth's surface should have a dew point of the temperature of 80°, when by article 1 the quantity of vapor would be one forty-eighth of the whole weight, it will be readily perceived by calculation that its specific gravity will be to that of dry air, as seventy-nine to eighty. And if a column of air eighty feet high, with such a dew point. could be introduced into a surrounding atmosphere of the same temperature absolutely dry, it would, by the principle of spouting fluids, begin to move upwards with a head of pressure of one foot, or with a velocity of eight feet per second.

8. If the surrounding air should not be absolutely dry, but have some lower dew point, this column would still move upwards, though with a less velocity, and continue

its motion (provided it is large enough to remain *en masse*) to the surface of the atmosphere; unless it becomes colder than the surrounding air, or enters into air of as high a dew point.

9. The latter case is not likely to happen; for it is known by observation that at great heights, the air becomes suddenly very dry, and the former cannot possibly occur, for the following reason: as the air in question contains $\frac{1}{48}$ of its weight in vapor, by calculating according to the principles contained in articles 4 and 5 it will be found that vapor contains, at the temperature of 12°, latent caloric enough to heat up forty-eight times its weight of air 100° Fahrenheit; and therefore, by the time it ascends high enough to condense by refrigeration one half of its vapor into water, it will be less cold by 50° than it would have been, had it been dry air ascending to that height; and then, according to article 3, it would be 50° warmer than the surrounding air at that height. The diminution of bulk by the condensation of this quantity of vapor would be by article 1, $\frac{1}{60}$ of the whole: and as it is known that air at 32° is expanded $\frac{1}{480}$ of its bulk for every degree of Fahrenheit, and as the mean temperature of the column would be about 32°, its bulk would be increased by the evolution of 50° of latent caloric, $\frac{50}{480}$ of the whole, or six times as much as it was diminished by the condensation of the vapor to water. And as the dew point of the ascending column would always be much higher than that of the surrounding atmosphere at the height to which the column had ascended, its specific gravity would be less on this account; and on the whole, at the moment when one half its vapor was turned to water, its specific gravity, when compared to that of the surrounding air at the same height, would be about as seven to eight.

10. It thus appears that whenever a cloud is formed in the atmosphere by refrigeration, the mass of air in which

the cloud is formed is prevented from contracting as much as it would otherwise do, by the latent caloric given out at the moment of the condensation of the vapor, and that too exactly in proportion to the quantity of vapor condensed.

11. The velocity of the cloud upwards will therefore depend on its perpendicular depth and on the height of the dew point; for on this last will depend the quantity of vapor condensed during the upward motion of the air. The theory will best be illustrated by calculating a particular case.

12. Suppose the dew point at 71°, when by article 1 the quantity of vapor in the air at the surface of the earth is $\frac{1}{64}$ of the whole weight. Suppose also the temperature to be 75°, or 4° above the dew point; suppose a column to begin to rise either from superior heat or superior moisture: and suppose an extreme case, unfavorable to the theory, that the column in ascending cools by expansion one and a half degrees for every hundred yards of ascent, while the atmosphere around the column is only one degree colder for a hundred yards; the effect will be, that the column will ascend only a little more than three hundred yards when some of its vapor will begin to condense. Now to ascertain what its temperature shall be at any particular height, sixty hundred yards for instance, we have only to find a point below 75°, at which sufficient vapor will be condensed to heat up the air as many degrees as this point wants of being one degree and a half below 75, for every hundred yards of ascent, or in the present case 90°. For as in this case the air is supposed to fall in temperature 90°, in ascending sixty hundred yards, there is nothing to prevent its falling this quantity but the latent caloric evolved in the condensation of the vapor. Now by examining a table of the dew point (129), according to Dalton, it will be found that if the temperature falls 48°, it will, after making allowance for the increased space it occupies, condense $\frac{20}{38}$ of its vapor, sufficient to heat

up the air 42°, which being added to 48° makes up the 90° which it would have fallen if there had been no latent caloric in the vapor condensed.

But as the atmosphere on the outside of the ascending column is 60° colder at the elevation of sixty hundred yards, and within the column only 48° colder, the specific gravity of the cloud will be at least $\frac{1}{40}$ less than the outer air at the same elevation, even without allowing anything for the 140° of latent caloric given out by the congelation of the water. In this calculation, no allowance is made for the greater specific heat of rarefied air, but this will be fully compensated by the 140° given out by the congelation of the water, and by the higher dew point in the column than in the surrounding air.

13. If it had been assumed that air, in ascending, falls only one degree for a hundred yards, then, according to the same mode of calculation, it will be found that by falling 36°, making allowance for the greater space now occupied by the air, sufficient vapor would be condensed to raise the temperature of the air 24°, and then, 24° added to the 36°, will make up 60°, which would have been the actual depression of temperature in ascending sixty hundred yards, if the vapor had contained no latent caloric.

It is not at all probable that the actual depression of temperature of air on being rarefied by diminished pressure, would be greater than one degree and a half for every hundred yards of ascent; but even if it should be two degrees, it will be found that the latent caloric evolved when the dew point is high, would prevent it from falling one degree for every hundred yards of perpendicular ascent, and therefore, even in this case, its specific gravity would be constantly less than that of the atmosphere at its own elevation.

14. If we suppose a very narrow column of air to begin to rise, as mentioned in article 12, and a cloud to be formed in it reaching to a height where the barometer would stand

only one-fourth of thirty inches, it will be then at a temperature of one degree at the upper end, and will have condensed two-thirds of its vapor capable of heating the containing air 50°, and then, according to article 13, it will be 50° warmer than the surrounding air at that height. And as the vapor condenses more rapidly in the lower part of the column than in the upper, the mean temperature of the whole column may safely be taken at 25° above the surrounding air; therefore, the mean temperature of the air being about 32°, the expansion of the columnar air will be about $\frac{25}{480}$, which would cause the mercury in the barometer to be depressed about one inch and a fifth, and cause a velocity in the column upwards of two hundred and fifty-six feet per second.

15. The quantity of rain produced by the refrigeration of this ascending column, would be five inches in one minute and twenty seconds, if it were all to fall on a space equal in area to the area of the column. This, however, could seldom happen, as the drops of rain would be carried upwards to a height greatly beyond the region of perpetual congelation, and thrown off at the sides in the form of *hail.*

16. The dew point in the above calculation was assumed at 71°; if it had been taken at 80°, to which it sometimes rises at Philadelphia, it would have been found that the barometer would in that case descend one inch and nine-tenths, and all the other effects would be proportionably aggravated.

17. It will readily be perceived that the air will spread out more rapidly at the upper end of the column than it runs in below, and thus, at some distance from the column, especially in front of the storm at the surface of the earth, the barometer will rise, and the effect of this will be to increase the velocity of the ascending column, for which no allowance is made in the preceding calculation.

18. It will also be perceived, that the air under the col-

umn being relieved from a pressure equal to an elevation of more than ten hundred yards, will fall in temperature more than 10°, and of course the cloud will reach the earth, unless the temperature of the air should be about 10° above the dew point, in which case it will reach very near to the earth.

19. In this case there will be a spout, and the air below the cloud reaching to the surface of the earth, the trees will be thrown inwards, and also forwards, if the spout has a motion along the surface of the earth.

20. The spout must have a motion on the surface of the earth, if there is a current of air at the upper end of the column, for this current will move the upper end of the column in its own direction, and the lower end will immediately advance with it. And as it is known that the uppermost stratum of air in which clouds appear, moves constantly at Philadelphia, and probably throughout the northern temperate zone, from a point a little south of west; and as it is certain that the upper end of the spout reaches far into this stratum, the motion of the spouts in this climate should be generally in this direction, or to a point a little north of east. Indeed, they will always move in this direction unless they meet with a middle stratum of air moving in a different direction.

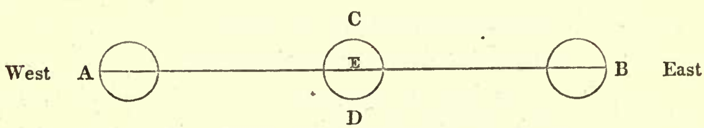
21. The narrower the spout is, the more readily will the air at the upper end be able to spread out and leave the column below free from the pressure of accumulation, and the more violent will be its effects at the surface of the earth.

22. If the dew point should be much below the temperature of the air, the visible spout or cloud will not reach the surface of the earth, and then the rain falling through the lower atmosphere may, partly by its impulse and partly by its cooling influence, (thus increasing its specific gravity) cause the air at the surface of the earth to move *outwards*

in all directions from the centre of the shower, especially in front, while all the time, the air at some distance above is running *inwards* from the circumference of the cloud at its lower borders, and of course upwards in the centre, and outwards in the upper parts. If we suppose a dew point 20° below the temperature of the air, we shall find, by calculating according to the law (article 3,) that the lower borders of the cloud will be a little more than twenty hundred yards high; and when the dew point is nearer the temperature of the air, the cloud will be nearer the earth at the lower extremity. This reasoning applies to clouds of moderate size.

23. But if the cloud is of great size, then the supply of air to keep up the ascending column cannot be afforded without reaching down to the surface of the earth, even when the lower part of the cloud may be at a considerable distance above the surface of the earth. Thus the law will become general, that *in all very great and widely extended rains or snows, the wind will blow towards the centre of the storm.*

24. From this law it will be easy to understand (when a round storm is in our neighborhood) not only the direction in which it is raging, but the course in which it is moving. For let



A E B be the direction in which the centre of a storm is moving, say from west to east, and C an observer to the north of that line, and D one to the south, when the storm comes within disturbing influence, as at A, the observer C will have the wind to begin to blow from a point north of east, and the observer D from a point south of east, and to the observer E, due east. When the storm shall have advanced to E, the wind to observer C will be changed round to north, and to observer D to south, blowing at that time with its greatest violence; whilst to observer E, it will be calm, without having changed its direction, only having gradually increased in violence, as the borders of the storm approached, and gradually diminished in violence as the centre approached. Moreover, if the storm is very violent and not very wide, the barometer at E will be very low when the centre of the storm is there, and there will at that time be no rain; for the upward motion of the air will carry with it the drops of rain, and throw them off at the sides; but, in the mean time, it will continue there very dark and cloudy.

As the storm passes onwards towards B, the wind will suddenly commence blowing from the west at E, increasing in force there for some time after it begins to diminish its violence at C and D, where it is now changing round respectively to west of north, and west of south. In like manner it may be shown, if the storm moves in any other direction, that this direction may be ascertained by a single observer, provided the storm is round.

25. If the velocity with which storms travel along the surface of the earth shall be ascertained, then not only their direction but their distance from a single observer may be known from the angular velocity with which the wind changes.

26. If it should be found, by further observation, that the uppermost currents of the air give direction to storms, it seems probable that near the equator they will be found to move from east to west. For, on the principle of the *conservation of areas*, when the air at the equator rises ten miles from the surface of the earth, it will be $\frac{1}{400}$ farther from the centre, and of course it will fall back towards the west by more than $\frac{1}{400}$ of the equatorial velocity of the earth, eastwardly by its diurnal motion, or about two and a

half miles per hour, besides the motion which it may have had towards the west at the earth's surface.

27. As this air rolls off down the inclined plane of the surface of the atmosphere towards the poles, it will, while near the equator, fall a little west of the meridian, but it will recede from the equator a few degrees only before by the diminished diurnal velocity of the latitude to which it has arrived, it will first move along the meridian, and then east of it, and thus, perhaps, storms near the northern tropic will be found to move towards the north, and storms near the southern tropic towards the south.

That the air does roll down an inclined plane in the upper parts of the atmosphere from the equator towards the poles will appear from the consideration that the mean temperature of the air in the torrid zone is about 80° greater than in the frigid zones, and as the mean temperature of the air in the frigid zones is about zero, the air is $\frac{80}{448}$ of its whole height higher at the equator than at the poles, or indeed very nearly that much higher at the tropics than at the polar circles.

The greater quantity of vapor, too, in the equatorial air, will cause it to stand about $\frac{1}{90}$ higher than the polar air, and, from these united causes, if the polar atmosphere is forty miles high, the equatorial will be about forty-eight miles.

It is of great consequence to meteorology, that the direction and velocity of these uppermost currents in the atmosphere should be ascertained.

It has been thought by some that the fall of an immense quantity of ashes on Barbadoes in 1812, upon an eruption of a volcano in St. Vincent, proved that the current of air at a great elevation in the torrid zone, is from west to east.

But when it is considered that the force of a rapidly rising column of air is great enough to cause the upper parts of this column to puff out even against a strong wind, we are warranted, from this circumstance alone, in rejecting the above inference.

If, indeed, the evidence was positive that no ashes fell to the west of St. Vincent, a current from the west in that particular case would be established. But here the volcano which broke out in Central America in January, 1835, comes to our aid; for this volcano threw its ashes in all directions, many hundred miles; to Jamaica in the east, and to the Pacific in the west.

Also the volcano of Tombora, hereafter to be mentioned, carried its ashes forty miles to the east, two hundred miles to the north, and three hundred to the west. The phenomena accompanying these two volcanoes, especially when connected with theoretical reasons, render it probable that an upper current of air as well as a lower prevails in the torrid zone, from the east, and if so it will give direction to storms in those latitudes towards the west.

I might go on to draw many other deductions, purely theoretical; but it will be more profitable to shew the power of the theory in explaining phenomena, and to see whether facts alone do not prove its truth.

It has been known, ever since the days of Franklin, who first discovered the fact, that our great N. E. storms at Philadelphia commence to the S. W., and Mr. Redfield of New York has shown that several hurricanes in the West Indies travelled from the south towards the north, gradually leaning towards the east as they approached the continent, and that in all instances the wind set in from a northern quarter, and terminated from a southern quarter.

It appears, also, in the Pennsylvania Gazette of September, 1772, that at St. Eustatias, on the 31st August of that year, the wind sprang up at north about eight o'clock A. M., increased till twelve, then changed to east till one o'clock, P. M., then S. S. E. where it blew a most terrible gale till twelve at night. At Santa Cruz, W. N. W. of St. Eustatias, about miles, it commenced about four P. M. of the same day from N. N. W. to N. W., and continued at that point till ten at night; then a lull for about half an hour, when the wind chopped round to S. W., and blew with greater violence for about two hours. Now if we suppose that the centre of this storm passed along a line lying nearly N. W. and S. E. between the two islands, the conditions of the theory would be exactly answered. At all events the wind was blowing a hurricane from one to ten hours, in opposite directions, towards a point nearly between the two islands; and when the wind changed at Santa Cruz it went by west, as, by the theory, it ought to have done, since the wind at St. Eustatias at that time was blowing in a direction, which would pass to the east of Santa Cruz. The lull however at Santa Cruz for half an hour, would seem to imply that the centre of the storm passed near the place of observation.

In Edwards's History of Jamaica, volume 3, page 620, the author says, " immediately before the storm begins the wind commonly blows hard for an hour or two from the west; which never happening but on such an occasion, the tempest may with great certainty be expected to follow. They begin from the north, veer back to the N. W., then W. and S. S. W., and when got round to S. E. the foul weather breaks up." The author says, " the wind always changes round this way;" but as he lived on the south side of the island, at Spanish Town, it is quite possible, that on the north side of the island, the wind may frequently back round the other way. Indeed, this is highly probable, independent of theory, from the statement made in page 608; that " when the wind is S. and S. W. on the south side of the island, it is often northeasterly on the north side, attended with very heavy rains." And again, he says, page 625, " it is curious to remark here the constant seeming attraction between the mountains and the rain." The rains fall heaviest on the mountains, the clouds tend to them, "and it is frequently seen raining there when it is perfectly dry on the plains below." Now if all these facts be taken in connexion with the great fall of the barometer, which the author says accompanies these storms, amounting to one inch and eight-tenths when the wind is S. W. and attended with great rain, it is certain, on dynamical principles, that the wind blows towards the storm, and therefore it must ascend in the region of the storm itself. And as it sometimes hails, we may infer that drops of rain are carried upwards at least three miles or more, to reach the elevation of perpetual congelation in that low latitude.

28. From the following hint of Shotte, in the Royal Philosophical Transactions for 1780, it appears that tornadoes on the western coast of Africa, in latitude 16° north have the same direction. He says, in the rainy season, beginning about the 15th of July, the wind is generally between east and south, from whence the tornadoes come. As the tornado approaches the breeze dies away, and a calm succeeds just before the tornado comes on.

And in the Edinburgh Journal for 1827, it is stated concerning squalls of wind and rain on the western shore of Africa, that for some time every day, at 9 o'clock, A. M., black clouds began to appear on the mountains, and generally reached the shore about two P. M., while all the time a gentle wind at sea was blowing towards the cloud.

It is not my purpose at present to enter into all the details of the theory; but there is one point, on which the truth of the theory manifestly depends, which requires a very particular notice: and that is, *does the wind blow towards the centre of a rain in the lower part of the cloud?* The following facts I trust will answer this question in a satisfactory manner.

29. On the 11th, 12th, 13th and 14th of May, 1833, there fell in the middle counties of the State of New York, in

some, four, and in others five and six inches of rain; during all this time the wind at Philadelphia was south: at the south east corner of New York, it was south east, and in the most northern counties, it was three of these days constantly north. At Philadelphia and in the south east parts of New York there was no rain when the wind was uniform, but in the most northern counties there was some rain, but not so much as in the central parts. The rain extended beyond the east and west boundaries of the state, and there the wind was variable; prevailing, however, in the east, from the east, and in the west, from the west.

30. On the 29th of January, 1835, while it was raining 1.47 inches at Nashville, the wind was blowing at Philadelphia towards Nashville, and when this same storm reached Philadelphia, which it did in twenty-three hours, the wind was blowing both at Nashville and at Flushing, New York, and at Middletown, Connecticut, and at Portsmouth, New Hampshire, towards Philadelphia. And in general, in our north east storms, the wind to the north east of them, and also to the south west of them, blows towards the storm, and if the centre of the storm passes to the north of Philadelphia, in all cases that I have been able to trace, the wind changes round by south, and when the centre of the storm passes to the south of us, the wind changes round by north.

31. On the 22d March, 1835, from eleven, A. M., till one, P. M., it was very calm, with a low barometer, but very dark, with thick clouds, which appeared to be almost stationary. The wind had been north east in the morning, with a little rain; during the hours in which there was a calm and no rain at Philadelphia, there was a most violent wind at York, Pennsylvania, towards Philadelphia, and also a very great rain; the same at Baltimore. At Cape Hatteras there was wind towards Philadelphia, and rain in sight towards the north east. At Flushing, New York, the

wind was towards Philadelphia, with moderate rain. The same at Middletown, Connecticut; Providence, Rhode Island; and Portsmouth, New Hampshire. In Berks county, the rain was most violent, as mentioned by the newspapers; direction of the wind not given.

This case corresponds exactly with the deductions of theory in article 24. This storm moved on to the north east, and the barometer stood lowest at Providence exactly six hours after it was lowest at Philadelphia. In the mean time, the wind had chopped round to north west at Philadelphia, with much rain.

32. On the 19th of June, 1835, about five, P. M., there took place in New Jersey a most violent land-spout. It appeared to all persons, in whatever direction it was viewed, in the shape of an inverted cone of cloud, reaching from a dark cloud above, down to the earth. It commenced about seven miles west of New Brunswick, and terminated at Perth Amboy, about seventeen miles from where it began, having travelled a little north of east, with a very moderate velocity, not exactly ascertained, probably not more than twenty-five or thirty miles an hour. It prostrated every thing in its path, which was from two hundred to four hundred yards wide; the trees on the north side being almost all thrown with their tops towards the south east, and those on the south side with their tops to the north east, and none with their tops outwards, as appears by a chart exhibited to the Am. Phil. Soc., by Prof. Bache. It unroofed the houses and prostrated their walls, many of them outwards, as if by explosion, and some light ones it lifted up nearly perpendicularly to a considerable height, and tearing up the floors of some whose walls remained standing. It carried the joists and upper floors and rafters, in some instances, to a considerable height, and threw them down on the north side of its path four hundred yards from the house, almost at right angles to its course, and exactly opposite to the course which the

wind must have blown at the ground in the yard, as manifested by the direction in which the trees were lying. It carried off shingles, and hats, and books, and various garments, and branches, and leaves of trees, and other light bodies, and threw them down on the north side of the spout, in a band of about four or five miles broad, and terminating on the north eastern side of Staten Island, about fifteen miles from Amboy, where the spout ceased to reach the earth, and twenty-five from where it took up the shingles. It threw these materials down *along with a severe shower of hail and rain.* These materials were seen to fall with hail and rain by a great number of witnesses whom I examined during the week which I spent investigating this spout. There was no hail and rain, at least as far as I could learn, on the path of the spout; it began about a mile on the north side of it, and became heavier a little further still, and then gradually diminished again as it approached the northern border. The hail was confined to the middle of the band.

33. After completing my examination of the Brunswick spout, I visited the tracks of nine others in New Jersey, New York, and Pennsylvania. They all exhibited the same phenomena as regards the direction in which the trees were prostrated, all being inwards and forwards. Two of these were of the present year, and I remarked in each of them, where they passed through fields of corn, that the stalks lay with perfect regularity — those on the north side of the path towards the south east, and those on south side towards north east, making nearly an exact right angle with each other. The only exception to this uniform regularity was, that in the Brunswick spout, three patches, nearly circular, with diameters equal to the width of the spout, were found with the tops of the trees all thrown inwards towards one common centre.

In the middle of one of these stood a large house, which had its roof carried off, and the trees all round the house had their tops thrown towards the house. The walls of the upper story, both on the north and south side, were cracked, and in one crack was thrust a lady's handkerchief, and in the other a sheet, which had been taken up from a bed in the room, and the cracks closed when they were carried partly through.

These facts leave no doubt that there is an upward motion of the air in the spout, and an inward motion below. And the fact that the hail and the shingles fell together, makes it equally certain that this hail had been formed from drops of rain carried up by the spout, above the region of congelation, and then thrown down along with the shingles carried up at the same time. The wind had been south west all day, which, no doubt, was the reason why all the shingles and hail fell to the north east of the track of the spout. There are many other highly interesting particulars connected with these spouts, which will be detailed in subsequent pages. I will only add, that the evidence which I collected was conclusive, that, at the time of the falling of the hail, the wind on the northern border of the shower was strong from the south, and on the southern border of the shower, strong from the north. This is a fact which will of itself explain why, in many showers, the wind at the *surface* of the earth blows in all directions from the centre of the shower, and yet, a few thousand feet high, it *may* be blowing in the under part of the cloud on all sides towards the middle of the cloud. This phenomenon I have more than once seen. (See article 22.)

34. Spouts at sea are manifestly the same in principle as spouts on land. They are always seen to descend from a a black cloud, sometimes with a velocity of half a mile in two seconds. Now this velocity precludes the possibility of this visible spout having fallen by gravity, for, in that time, if its specific gravity were ten thousand times greater than it is, it could not fall more than sixty-four feet in two se-

conds. But, as the theory shows that the condensation of the vapor must commence above, and descend lower and lower as the column becomes lighter and lighter, whilst all the time the individual particles of the visible spout are moving upwards, so it is manifest that the condensation of the vapor may commence lower and lower with great rapidity, as the air down to the very surface of the sea may be very rapidly relieved of part of the superincumbent weight by the expansion and outward motion of the air in the upper part of the spout.

35. The theory also accounts most satisfactorily for the violent showers of hail and rain which are known to accompany, or immediately succeed spouts both by sea and land.

36. It also accounts for the sudden and great depression of the barometer on the passage of a spout. In Orkney, during a spout which threw down nine inches of hail in eight minutes, the barometer fell more than one and a half inches. Article 16. (See Edin. Trans. Anno 1823.)

37. It also accounts for the great and continued rains which are known to accompany the breaking out of volcanoes. The mighty mass of aqueous vapor which is thrown out sometimes from a volcano, in condensing, will heat up the air by its latent caloric and cause it to rise and spread out in all directions above. Then the air will rush in below, and a violent upward motion will be established first in the immediate neighborhood of the volcano; and unless the dew point is extremely low, a rain must be the consequence, and as the rarefied air spreads outwards in all directions above, the circumference of the rain may become wider and wider, receding from the volcano in all directions, but faster on that side which has the higher dew point. In the meantime, the barometer on the outside of the circle of rain at some distance will rise, and within the circle of rain will continue to fall; and if within the circle, six inches of water at a mean should fall, the barometer will have fallen above

two inches, (article 16), and the air near the surface of the earth, at the borders of the storm, would be rushing inwards with a velocity of 370 feet per second.

38. In the year 1821, on the 19th of December, a volcano broke out in Iceland, attended with just such phenomena; and in five days the rains reached the south of Europe, and the barometer on that day, which had been gradually falling, stood all over Europe lower than it had done for many years. (See the Phil. journals of 1822.) Thus that mysterious connection between volcanoes and rains which, Humboldt says, is even able to change the rainy seasons in South America, is clearly explained. Nor will such accounts as the following any more appear incredible.

In the mountain of Tomboro, in the island of Sumbawa, eastward of Java, a most dreadful volcanic eruption commenced on the 5th of April, 1815, and was most violent on the 11th and 12th. Out of a population of twelve thousand persons, only twenty-six escaped destruction. Violent whirlwinds swept away men, horses, cattle, and every thing which came within their vortex, tore up the largest trees, and covered the neighboring sea with floating timber, which, from its scorched appearance, had evidently been carried through the flames of the volcano.

39. In Scoresby's Arctic Regions, page 404, vol. 1, are several facts which would of themselves prove an upward motion of the air at the time of a storm.

" About 10 o'clock the snow abated, and several ships were seen within three or four miles. As all of these ships were sailing on the wind, it was easy to ascertain the direction of the wind where they were.

Two ships bearing north east from us had the wind N. E.; two bearing east, at E. or E. N. E.; two bearing south east, had the wind S. E.; while with us it blew from the north west. In each of these places, a fresh breeze prevailed; but in some situations where there happened to be no ships, there appeared to be no wind at all. The clouds above us at the time were constantly changing their forms, and showers of snow were seen, in various places, at a distance."

40. At another time, he says, "While a gentle breeze from the north prevailed with us, a heavy swell from the S. S. E. came on, and a dense black cloud appeared, in the southern horizon, which rapidly rose into the zenith, and shrouded one half of the heavens. The commixture of this dense air with the cold wind from the north, produced a copious discharge of snow. When the snow ceased, (though we were nearly becalmed) we observed several ships a few miles to the south-eastward, under close-reefed topsails, having evidently a gale of wind, blowing in the direction of the swell. In about two hours the southern wind reached us, and as we stood to the eastward, gradually increased to a gale. Previous to this storm, the barometer fell three-fourths of an inch in twelve hours.

41. Now as the wind in both these storms blew in all directions towards a particular point, it must have blown upwards over that point, and hence the snow was not permitted to fall at that point where there was nearly a calm, but fell in "various places at a distance." It is equally plain that a strong gale could not blow in sight of Captain Scoresby two hours before it reached him, without blowing upwards at some point between him and the ships seen laboring in the gale.

42. A remarkable circumstance which I think can only be explained on the supposition that the cloud mentioned, moved upward, is related on the next page. He says: My father was engaged in admiring, in a particularly fine day, the extensive prospect from an eminence, on Charles' island, of about two thousand feet high, when the rapid approach of a small cloud attracted his attention. When it reached the place where he was sitting, in a calm air, a torrent of

wind assailed him with such violence, that he was obliged to throw himself on his body, and stick his hands and feet in the snow, to prevent himself from being hurled over the tremendous slope which threatened his instant destruction. The cloud having passed, the air became calm, and he immediately descended. Now this is just the effect which would be produced by a large mass of air moving upwards rapidly by being of less specific gravity, than the surrounding air; which is too plain to need demonstration.

43. Gay-Lussac, on entering a cloud with his balloon, found his thermometer rise several degrees above what it had been in the sun's rays.

44. The Reverend W. B. Clarke says, in the Magazine of Natural History, volume 7, page 300, that Mr. Kelsall, who was an eye witness of the great eruption of Ætna, in 1809, writes thus: "At fifteen minutes past nine, A. M., April 1st, a quantity of dense smoke proceeded from two rents, which, raised to a considerable height in the atmosphere, before serene, was dilated, and formed a black cloud above two thousand paces in diameter, which presently discharged a copious shower of large hail stones, on the red hot lava."

In the same page he says that "during the eruption of a volcano in Iceland, in 1793, not only did rain fall in torrents, but also *hail* in showers."

45. Mr. J. R. Jackson, in his Aide-Memoire Du Voyageur, says, "I have seen, in the plains of Agra, Hindoostan, latitude 27, enormous columns of sand, sometimes thirty at a time, several feet in diameter, rising perpendicularly out of sight, and followed frequently by a shower of large hail stones, containing such a quantity of sand, in large grains, that in filling a goblet with this hail when it was melted there was a sediment of sand almost half an inch thick." From these accounts it is manifest that *hail* is sometimes produced by an upward motion of a column of air both with and without volcanic agency; and it is confidently believed that

no theory of hail can stand, which does not show how drops of water are first formed and afterwards frozen.

46. Again: nothing can be more satisfactory than the explanation which the theory affords of the immense quantity of rain and hail which sometimes falls, in a very short time on a very small extent of land. Nothing is wanted for this purpose, but the stoppage, for a short time, of the horizontal motion of the spout.

47. This may be effected by a mountain or island of the proper height. If it is very high, as the Himalayas, the rain and snow will be all on the windward side; if it is barely sufficient to cause a condensation of vapor when the air blowing over it comes to the top, the spout will be so formed as to discharge its water on the leeward side, for as it ascends above the point of condensation, it will be pressed over to the leeward side by the prevailing current of air.

48. On the 26th of July, 1819, the mouth of the Catskill, eight miles east of the Catskill mountains, previous to the storm, the air was thick and sultry, clouds low, and wind south west. About five P. M. two very dense black clouds were seen to rise up, very rapidly to the zenith, one in the north east, the other in the south west, and at the same time two sloops in the North River were seen approaching each other under a full press of sail. Immediately on the meeting of the clouds there commenced a violent rain which did not abate for one hour and did not entirely cease for three hours and a half. During this period there fell at least fifteen inches of rain over a space of about nine miles in diameter, bordering on the Catskill.

This account is given, with a great many other particulars, by Benjamin W. Dwight, in the fourth volume of Silliman's Journal; but the direction of the wind, in the borders of the shower, is not given.

49. In the Ann. de Chem. et de Phys. for February, 1835, M. S. Berthelot gives a very particular account of a storm

which ravaged the northeast part, particularly, of Teneriffe, on the 6th of November, 1826. As in the preceding case the wind had been from the southwest till the commencement of the storm, when on the east side it began to blow most violently from the east, and on the north side most violently from the north, and continued in this way for more than six hours. It does not appear how it was blowing at this time on the south nor west side. One observer, at the commencement of the storm, saw the clouds all round the horizon rapidly approaching to the zenith. The quantity of rain which fell on the northeast side of the island must have been immense. In some places it fell in such torrents as to make excavations six hundred paces in circumference, and twenty or thirty feet deep.

50. Was the spout in these two cases kept stationary for some time by the height to which the southwest wind, surcharged with vapor, had to ascend in passing over the mountains?

51. The barometer in the Teneriffe storm sunk suddenly two-thirds of an inch, which would give a velocity of upward motion in the ascending column, of one hundred and twenty-five feet per second. And if the dew point were known at the time of the storm, the quantity of vapor condensed in a given time could be calculated.

52. I hope that meteorologists in future will pay more attention to the dew point, and to facilitate their observations I will observe that the dew point may be obtained indirectly by the following method.

53. Take two thermometers, (Fahr.) which agree, or allow for the difference; cover the bulb of one of them with a wet rag; swing them both briskly in the air until they both become stationary; multiply their difference by 103, and divide the product by the number of degrees expressing the wet bulb temperature; subtract the quotient from the dry bulb temperature, and the remainder will be the dew point.

This law holds good for a wet bulb as high as 75°, and as low as 20°, as I have verified by many hundred experiments. Near the freezing point, however, great care is necessary that the water should either be *all* frozen or *none*. And what is not a little remarkable, I have frequently observed when the temperature of the air is only a little above the freezing point, and the dew point much below, that two thermometers would exactly agree at all temperatures between 32° and 27°, one being covered with ice, and the other with a wet rag. Lower than 27° the wet rag would always freeze. I may add here, that it is essential to swing or blow the thermometers, for the wet and dry bulbs will always indicate a greater difference when they are blown than when they are in still air. As these experiments are both contrary to the doctrines of Leslie, now considered correct in Europe, I have been at the greatest pains to put them to the strictest scrutiny.

54. I have now mentioned only a few of the many facts which I have been able to collect in favor of a theory which explains, with the simplicity of the law of gravitation, many phenomena which have heretofore baffled all attempts at explanation, and some which have not ever been attempted. Enough, however, have been adduced to establish, beyond the possibility of doubt, the leading *fact* in the theory, the upward motion of the air in the region of a cloud at the time of its formation; and as the explanation of this upward motion is founded on facts established by the most careful experiments made by such men as Black, Dalton, Gay-Lussac, Ure, Berard and Delaroche, and Clement and Desormes, and Petit and Dulong, the theory may claim for itself not merely plausibility, but absolute certainty. When the ancients were amusing themselves by demonstrating the properties of the sections of the cone, they little thought what aid their investigations would afford to the future astronomer. So the chemists, who dis-

covered the latent heat of steam and the specific caloric of atmospheric air, could hardly be aware that from their discoveries would soon arise a theory of meteorology, explaining so many atmospheric phenomena.

The substance of the foregoing pages was written in the autumn of 1833. It will serve to show how I proceeded with my investigations at this early period.

55. At the time of writing this theory the only point at all doubtful was the specific caloric of air; I am happy to have it now (January, 1836,) in my power to remove every vestige of doubt on this point, by two new and entirely independent methods.

First. Professor Apjohn, of the Royal College of Surgeons, Dublin, has given a formula[1] for calculating the dew point, assuming as one of the data the specific caloric of air as given by Delaroche and Berard. I have calculated a great number of my own observations, including a range of artificial temperatures of the wet bulb, from 94° to 20° Fahr., and I find they give the dew point within the limits of the errors of observation; below that point they begin to deviate rapidly from the true dew point; but this deviation may fairly be attributed to the tables of the elasticity of vapor, as given by Dalton and Biot.

By inverting the formula of Professor Apjohn, as I understand it, and calculating the specific caloric of air from my observations of temperature of air, wet bulb, and dew point, it comes out almost exactly what it is assumed in the essay. I say, as I understand it; for, as I understand it, I make the specific caloric of hydrogen about fourteen times greater than the professor does, which must arise either from my misunderstanding his formula, or from an inaccurate calculation on his part. We agree in the specific caloric of atmospheric air.[2]

[1] Lon. and Edin. Phil. Mag. and Jour. of Science, for Nov. 1835.

[2] It appears since, that Professor Apjohn had neglected to allow for the specific gravity of hydrogen.

MARCH, 1835.

Day.	Hour.	Temperature.	Wet bulb.	Dew point.	Dew point by Espy's Formula. See Art. (115).	Dew point by Apjohn's Formula.	Difference by Espy's Formula.	Difference by Apjohn's Formula.	Barometer.	Specific caloric of air.
1	8	10.5	9.4	—3	—1.6	+6	+1.4	+9	30 50	
	3	18.8	15.5	—3	—3	+4.1	0.	+7.1	30.51	
2	3	29.7	24.6	+8.5	+8	+13.5	—0.5	+5	30.52	
3	4	21.7	18.2	0.5	+1.7	+7.1	+1 2	+6.4	30.52	
4	3	24.7	20.4	2.5	3.1	+7.8	+0.6	+5.3	30.74	
5	3	30.2	25	8	8.7	+14.5	+0.7	+5.5	30.67	
12	3	46.1	39.7	28.9	29.5		+0.6		30.25	
				JUNE, 1835.						
13	2	86.0 / 85.7	73.5	68.7	68.7 / 68 6	69.6	0 / —0.1	+0.9	30.02	0.231
15	3	70	59.5	51.6	51.7	51.5	+0.1	—0.1	30.12	.245
16	3	73	61.5	53.7	53.8	53 4	+0.1	—0.3	29.93	.245
17	3	77 2	60	49.8	50.5	49.8	+0.7	0	29.93	.281
18	3	72.2	64.6	57.4	57.2	57	—0.2	—0.4	29.90	.245
19	3	82 2 / 82	73.5	69.7	70.0	68.5	+0.3	—1.2	29.63	.267
20	3	70.1 / 70.3	56	44.5	43.3	44	—0.5	—1.2	29.82	.255
21	3	66	51.5	37.5	37	36.6	—0.5	—0.9	30.00	.245
				ARTIFICIAL TEMPERATURES.						
		130	74	36	Espy's Formula not suited to high temperatures.	29.8				0.252
		138	77	35		33.5				.267
		177	87	35		34				.276
		192	92	33.5		38.5				.269
		180	87	33.5		29				.259
		204	94	35		39.5				.283
		153	82	35		38.2				.285
		120	76	52		50.2				.244
		101	71	52		52.1				.261
		101	71	52		52.1				.261
		108	68	35		35				.272

57. The above table is taken from my journal of the weather kept in Philadelphia, for some of the coldest and warmest weather in the year. And, besides, some artificial temperatures are used, in which the thermometers were put into a hot stream of air, ascending through an opening in

the floor from a stove below. These last were made in Professor W. R. Johnson's parlor, and confirm the accuracy of this manner of finding the specific caloric of air so as to leave no doubt on the subject. The mean of all the experiments is 0.259. The table is not without interest, also, as a specimen of the hygrometric state of the air in our climate. The reader will perceive that these tables of dew points and wet bulbs were made previous to Professor Apjohn's formula reaching this country, so they could not have been got up for the purpose of sustaining a theory.

58. The formula I have used in calculating the specific caloric of air is $a=\frac{(w-w')e}{d}$, a being the specific caloric of air, w and w' the respective weights of vapor in the atmosphere when saturated at the temperatures of wet bulb and dew point, and d the difference of the temperatures of air and wet bulb when in a brisk current of air, the weight of atmospheric air being taken at unity, when under mean pressure, for I have not found that changes in the barometer affect the question, though I instituted a very extensive series of observations with that view. And e is the latent caloric of vapor at the wet bulb temperature, which I have assumed equal to the difference of the wet bulb and 1212°.

59. Second. I instituted a series of experiments to ascertain, independent of chemical laws, whether air is more expanded by the evolution of latent caloric when a portion of its vapor is condensed into water than it is contracted by that condensation. The result, it will be seen by the table below, is abundantly confirmatory of the theory.

I took a copper vessel containing about a gallon, furnished with a stop-cock, and bent tube mercurial gage. I transferred this vessel with the stop-cock closed from one temperature to another, and carefully waited till the gage became stationary. I then measured the height that the mercury stood in one leg above that in the other; the stop-cock was then opened and closed as soon as possible after the mercury came to a level in the two legs; the mercury in the gage would then instantly begin to change its level, and in a short time become stationary again; the difference of level was then measured, and the whole recorded in the table under article 64.

60. This was done both with dry air, and with air saturated with moisture, with a view to ascertain the difference of temperature caused by the condensation of the vapor.

This difference of temperature would be indicated by the difference of rise of the barometer gage from that which took place in dry air—allowance being made both for the quantity of vapor discharged and condensed at the moment of turning the stop-cock and letting the air in the urn expand; for it is manifest that this same quantity would be again evaporated when the air became heated to its original temperature. Now, it will be seen, that when dry air was used, the cooling due to expansion was about one degree for every four and fifteen hundredths that the air had been heated: but when moist air was used at the temperature of about seventy-five, the cooling effect of the expansion was only one degree in six, and $\frac{4}{10}$ even without allowing any thing for the rise of the gage by the vapor, and as this is more than one third of the whole at the temperature employed, the real depression of temperature in this case is only about four ninths of that in dry air.

At the temperature of about 100°, which was tried though not recorded, the result was equally striking and confirmatory of the principle. Here the rise of the gage after opening and shutting, was about one in five of the original height, though one half of this effect is due to the vapor, as will be seen by examining a table of dew points, (129); and, therefore, at this temperature, the cooling effect of the expansion of moist air when compared to that of dry, is about as four to ten.

61. A similar effect will be observed, by examining the result when the urn was carried from a warm to a cold place.

A much greater effect was produced in this latter case than in the former, when moist air was used, which can only be accounted for, on supposition that there is a great expansion of air containing vapor, when a portion of that vapor is condensed into water.

62. This point being now established, independently of all previous experiments on the specific caloric of atmosphereic air and the caloric of elasticity in steam, it adds a high degree of probability, *a priori* to the dynamic theory of atmospheric depositions given above.

63. I do not pretend to draw from these experiments, the specific caloric of air, though I may perhaps attempt this by a more careful set of similar experiments at some future time.

64. The minus pressures, or where the apparatus was transferred from a warm to a cold medium, are very important, indeed quite decisive in a comparative point of view. For if the instantaneous heating and cooling effect of the vessel on the included air at the moment of opening the cock should be so considerable as to hinder us from drawing any certain conclusions as to the exact number of degrees air is heated by a given condensation, or cooled by a given expansion, still, as these experiments were performed with the same instrument and in the same manner, the *comparative* results must be correctly obtained.

It is proper to mention, that to insure saturation, a small quantity of water was put into the urn, in the case of moist air.

AIR SATURATED WITH MOISTURE.

PLUS PRESSURES.					MINUS PRESSURES.				
Temperature on closing.	Temperature before opening.	Difference in two legs, quarter inches.	Difference after opening, quarter inches.	Ratio of 2d to 1st.	Temperature on closing.	Temperature before opening.	Difference of two legs, quarter inches.	Difference after opening, quarter inches.	Ratio of 2d to 1st.
31	76	9	1.5	1 : 6	76	40	9.60	1.70	1 : 5.64
		9.5	1.25	1 : 7.68					
					80	38½	10.4	2 5	1 : 4.16
38½	79	10.5	1.75	1 : 6	79	38	9.5	2.5	1 : 3.8
38	79	9.5	1.50	1 : 6.36	79	36	8.5	2 1	1 : 40
36	84	13	2.05	1 : 6.34	85	36	11	2.65	1 : 4.15
36	73	6.5	0.9	1 : 7					
73		12.00	1.60	1 : 7.5		32	15.66	3.50	1 : 4.7
81½		5.50	1.00	1 : 5.5	70.5	20.5	7	1.7	1 : 4.3
23	80	16.33	2 40	1 : 6.8	81	23	11.00	2.25	1 : 4.4
23	86	17.00	2.60	1 : 6.9	80	23	12.5	2.9	1 : 4.3
23		23	3.6	1 : 6.4	86	23.4	13.2	2.7	1 : 4.8
76		19.75	3.00	1 : 5.9		23	16.5	3.7	1 : 4.4
70		11.30	2.20	1 : 5.1		77	13.60	3.00	1 : 4.5
41.2	78	12 33	1.70	1 : 7.2	70	41.2	9 00	2.20	1 : 4.1
41	81	12 75	1.90	1 : 6.4	78	41	11.75	2.75	1 : 4.2
40	81	12.10	1.80	1 : 6.7	81	40	11.50	2.7	1 : 4.3
	66	5.9	1.00	1 : 5.9				mean	1 : 4.39
	86	13.8	2.3	1 : 6.0					
			mean	1 : 6.4					
URN DRIED AND AIR IN IT AT DEW POINT 16.°									
	83	12.20	3.25	1 : 3.75	83.0	27	12.30	2.80	1 : 4.4
27	82	13.00	3.40	: 3.83	82	25	12.66	3.10	1 : 4.0
25	76	13.10	2.80	: 4.68	76	23	11.30	2.60	1 : 4.3
23	80	13.60	3 25	: 4.32					
AIR DRIED WITH CHLORIDE OF CALCIUM.									
37	75	7.25	1.70	1 : 4.28		37	12.25	2 60	1 : 4.70
	72	9.40	2.30	1 : 4.08	75	20	10.33	2.33	1 : 4.44
	81	6.70	1.40	3.94					
20	83	15.75	3.70	1 : 4.25	83	18	14.70	3.00	1 : 4.90
18	84	15.90	3.80	1 : 4.18	84	15.5	15.00	3.50	1 : 4.27
15½		24.75	6.10	1 : 4.10		13	22.25	4.80	1 : 4.63
13	76	14.60	3.30	1 : 4.42	76	12	12.75	2.80	1 : 4.55
		9	2.10	1 : 4.29					
		12.60	2.90	1 : 4 34					
			mean	1 : 4.15				mean	1 : 4.46

65. The grand object then for which these experiments were instituted, is established beyond doubt — *that the latent*

caloric of vapor, causes the air to occupy much more space when it is imparted to the air, than when it is united with water in the form of vapor.

66. But as it is very desirable to know the exact amount of this expansion of air by the latent caloric of vapor, and also how much vapor at a particular dew point is condensed by ascending into the air a given height; and also how high air of a given dew point will ascend before it forms a cloud, let us see what information our experiments give us on these interesting points.

Now it appears from the experiments on dry air, that on opening the cock, and letting the air expand into equilibrium, it was cooled nearly one fourth the number of degrees to which it had been heated after the cock had been closed. And this law appears to be observed at all the different temperatures.

It appears, therefore, at least for small elevations, that when air ascends, it becomes colder about $1\frac{1}{4}°$ for every one hundred yards: and it will also be found by calculation, that the dew point falls about one quarter of a degree on account of the greater space occupied by the air and vapor for every hundred yards of ascent; and from these elements it follows, that when air ascends from the surface of the earth on account of greater heat or greater moisture than surrounding columns of air, it will begin to form cloud when it rises about as many times one hundred yards as the temperature of the air is above the dew point in degrees of Fah.

The method of obtaining this result will be understood by the following example: suppose the temperature of the air to be 70° and the dew point 60° — suppose that a portion of air at the earth's surface should rise ten hundred yards, it appears by experiments, that it would sink in temperature, from the expansion due to diminished pressure, $12\frac{1}{2}°$— and as the barometer would at this height fall three inches or one tenth of the whole, and consequently the air which ascended would have expanded into nearly one tenth greater space, and, therefore, each cubic foot of it would contain nearly one tenth less vapor. Now, by examining a table of dew points (129), it appears, that the elasticity of vapor at 60° Fah. is .524 inches, and one tenth of this subtracted from it, leaves .472, which corresponds to a dew point of 57°. This is the point to which it would be reduced, if it suffered no reduction of temperature by expansion.

But as by the experiments it would be cooled about $12\frac{1}{2}$°, and contracted on this account about $\frac{1}{40}$ of its whole volume, therefore a correction of the above estimate must be made by adding $\frac{1}{40}$ of 472 to 472 = 484, which corresponds to a temperature of $57\frac{2}{3}$°; and this is the actual dew point of air having ascended from the surface of the earth one thousand yards, having had a dew point of 60° previous to its ascent.

Now as the temperature of the air in this case would fall about $12\frac{1}{2}$° in rising one thousand yards, it appears from this calculation, that the temperature and dew point would at this height almost coincide, and upon a farther ascent and diminution of temperature, a cloud would begin to form.

67. By a similar calculation for other dew points, I find that *the bottom of all cumulus clouds at the moment of being formed, is about one hundred yards high for every degree of difference of the temperature of the air, and the dew point at the time of formation.*

This rule requires a small correction when the air is very dry, arising in extreme cases to about one hundred and five yards for one degree.

68. This rule, however, applies only to the base of clouds before they have acquired very considerable perpendicular diameter. For as a cloud goes on increasing in height at the top, the base descends, in consequence of the levity of

the cloud, and the expansion of the air under the cloud, but the exact amount of this descent for a given cloud, cannot, at present, be calculated, because it is not known exactly what the temperature of the atmosphere is at very great heights, and, therefore, the comparative specific gravity of the cloud and of the surrounding air, cannot be precisely estimated. It will, however, be near four hundred yards for a fall of the barometer one inch, and eight hundred yards for a fall of two inches under the cloud.

I would not wish to be understood here as saying by implication, that the numbers used in this paper are *strictly* correct. These numbers are introduced chiefly for the purpose of illustrating the theory. Yet as they are all within the range of nature and generally near approximations to the truth, they may be assumed as true, until future investigations shall furnish strictly accurate results.

June 10, 1841.

I have, at various times since the experiments recorded above were made, performed a much more extended series of similar experiments, with a similar urn or vessel of *glass*, in which the cloud could be seen when moist air was used.

To enable me to use higher pressures and greater relative rarefications on opening the stop cock, I had a condensing pump attached to the vessel, by means of which I could force in air to any desirable amount. After this was done, I let the instrument stand till the air within was the same in temperature as the air without. I then measured how much higher the mercury stood on the outer leg of the gage than on the inner. This gave me the degree of condensation. I then opened the stop cock, and let the air fly out, and at the moment of equilibrium of pressure within and without, I closed the cock, holding fast the air within, at the moment of its greatest cold produced by the expansion.

In short, I performed experiments with the instrument thus modified, both on dry air in which no cloud could be formed, and in air saturated with vapor, in which a dense cloud was formed, and the results for small expansions, do not vary materially from those given above. The instrument, thus modified, I have named a *nephelescope*, or cloud-examiner.

It was soon discovered, however, on using high degrees of condensation, that the ratio of cold produced by the expansion of air from diminished pressure, was a decreasing one, as the quantity of air pumped into the nephelescope was increased.

What the exact ratio of this decrease is, I am not prepared to say; probably as the square root of the density of the air previous to expansion. It is very desirable to know this law; and perhaps, by a careful set of experiments, performed with the nephelescope on dry air, it may be discovered.

I have given below a few experiments at different densities. The measures are all in quarter inches and tenths of quarters.

DRY AIR.					MOIST AIR.			
Barometer.	Temperature.	Quantity of air pumped, in quarter inches.	Quantity of rise after expansion.	Ratio second to first.	Barometer.	Temperature.	Quantity of air, in quarter inches.	Quantity of air after expansion.
30.10	64°	8.45	2.05	4.01	30.04	89°	40.4	5.2
30.10	70	8.90	2.15	4.14	30.04	89	40.1	5.05
30.22	64	9.30	2.25	4.13	30.04	87.2	40.25	5.2
30.12	70	9.00	2.20	4.09	30.04	87.2	40.25	5.2
30.22	64	38.8	8.60	4.49	30.04	89.2	16.1	2.25
30.16	70	42.5	9.15	4.62	30.04	89.	16.1	2.25
29.98	58	37.4	8.25	4.53	30.04	89.	24.1	3.25
30.00	64	40.0	8.60	4.58				
29.75	73	71.9	14.1	5.10				
29.75	73	72.5	14.2	5.10	ARTIFICIAL TEMPERATURE.			
29.71	76	75.6	14.5	5.21				
29.75	72	88.2	17.	5.19	29.99	102	24.2	3.5
29.75	71	98.2	18.5	5.3	29.99	103	24.3	3.4
29.65	75	100.9	18.8	5.38	29.99	104	23.9	3.3
29.70	71	99.25	18.15	5.49	29.99	105	24.4	3.4
29.70	75	101.4	19.00	5.34				
29.61	76	86.0	16.7	5.15	30.04	89.	90.5	10.8
29.85	75	82.0	15.55	5.27	30.	88.7	90.5	10.7
					29.82	76	91.3	11.25
30.05	64	22	5.15	4.27	29.81	48	64.8	9.6
30.02	64	22	5.10	4.31	29.81	49	65.4	9.75
30.01	64	22.3	5.3	4.20	29.71	76	101.7	12.7
30.01	63.7	22	5.15	4.23	29.70	75	101.0	12.5
30.00	45	21.6	4.95	4.36	29.65	71	101.6	12.9
29.97	46	21.75	5.20	4.18				

On comparing together the experiments made on dry air, there appeared but little discrepancy, but this was not so with moist air; and I was induced to institute a set of experiments, to see whether length of time in performing the experiment had any influence on the result. I therefore performed a great number of experiments, similar in all respects except the length of time which intervened between the time of pumping air into the nephelescope and of letting it out, and to my astonishment I found, the rise of the mercury after the discharge, constantly greater, as the time was longer — up to about twelve or fifteen days; but beyond that time the effect did not seem to be increased. It follows from these experiments, that when air, saturated with vapor, is confined in a glass vessel, air tight, and containing a small portion of water, it will cease to be saturated to the amount of about 4 or 5 degrees in fifteen days.

Whatever may be the cause of this remarkable fact, so contrary to all our notions since the experiments of Dalton on the subject of the dew point, the following table of experiments proves beyond all doubt that it is a fact.

Does water or glass so attract the particles of aqueous vapor in contact with them, as to condense some of these particles on them, and bring down the dew point 4 or 5 degrees below the temperature of the water, and the air included in the vessel? The fact that air near the surface of the ocean has generally a dew point several degrees below the temperature of the water, would seem to lead to an affirmative answer to this question, more especially as it is now known, that aqueous vapor does not permeate the pores of atmospheric air, and cannot rise into the upper regions of the air, in any way except by the motion of the air itself.

MOIST AIR.

Temperature.	Barometer.	Rise after expansion, quarter inches.	Quantity pumped, in quarter inches.	Time between condensation and expansion.	Month.	Day.
76	30.24	5.9	41.	1½ hours	February.	10
76	30.24	1.15	5.9	10 minutes	"	10
74	30.00	8.9	41.5	20 hours	"	11
76	30.09	2.4	10.	4 days	"	15
70	30 06	2.3	10.3	28 hours	"	16
76	30.18	1.7	7.7	3 days	March.	16
75	30.23	1.9	8.25	3½ days	"	20
74	29.85	5.2	23.50	4 days	"	29
74	29 85	3.2	23.60	1 hour	"	29
76	29.80	3.45	24.	3 hours	"	29
77	29.74	3 2	23 7	3 hours	"	29
75	30.17	5.4	23.2	5 days	April.	3
75	30 17	3 5	24 1	3 hours	"	3
76	29.81	5.6	25.5	5 days	"	8
76	29.81	3.25	25 3	10 minutes	"	8
71	30.06	5.	22.2	30 hours	"	10
70	30.03	3.	21.8	3 hours	"	10
70	29.96	5.8	25 7	25 days	"	27
70	29.96	3.5	25.9	1 hour	"	27
70	29.81	2.1	11.5	18 hours	"	28
72	30.13	8.75	65.9	7 days	May.	6
72	30.13	1.6	8.75	15 minutes	"	6
72	29.83	2.7	11.40	9 days	"	15
72	29.83	1.75	12 20	6 hours	"	16
68	29.90	4.0	17.70	3 days	"	25

SECTION SECOND.

THEORY CONFIRMED BY AN EXHIBITION OF ITS POWER IN EXPLAINING PHENOMENA.

69. POUILLET has given an account of a hail storm which extended from the Pyrenees to the Baltic, on the 13th of July, 1788, in two bands, parallel to each other, about fifteen miles apart, in which space there was a great rain. The eastern band was, at a mean, about six or seven miles broad, and the western band about twelve miles. The rain, however, was on the outside of these bands of hail, as well as between them. The progress of the storm from the south west to the north east was about fifty miles per hour, and the hail continued to fall not more than eight minutes at any one place, yet the devastation was immense, the largest of the hailstones being about eight ounces.

If I had made this storm myself, it would be said that I had made it to illustrate my theory. For it is manifest that the outspreading of the air above, will, in many cases, carry with it the hailstones, and those which are least the farthest, and these smaller hailstones, on the outside of the bands, will melt before they reach the earth, while the larger hailstones, falling more swiftly, and having more ice to melt, may reach the earth in the form of hail. Thus the two veins of hail, and the rain on the outside of them, are manifestly accounted for; it is not quite so plain why it should only rain in the middle. Nevertheless, if we consider that the vortex moved with a velocity of fifty miles an hour from the south west to the north east, we will readily perceive that, as it would require perhaps twenty or thirty minutes for the drops of rain to be carried up to their greatest elevation, and to fall down to the earth, during which time the up-moving column would move forward twenty or twenty-five miles, neither hail nor rain could appear in front of the vortex, and as it could not fall in the middle of the spout, being prevented by the force of the ascending air, whatever fell between the two bands of hail must have descended in the hinder part of the ascending column, where it would not be likely to descend, on account of its upper part leaning forwards.

70. The correctness of this explanation acquires additional probability from the fact that, in hail storms, the hail almost always precedes the rain, as appears from the facts collected by Pouillet. After mentioning the facts connected with this remarkable storm, this highly enlightened philosopher says: "In explaining the meteor hail, there are but two difficulties; but these are great, and we may say, in advance, they remain above all the efforts which have been made to resolve them.

"First. To explain how the cold is produced which congeals the water, and then to show how a hailstone which has acquired sufficient volume to fall by its own weight, remains yet suspended in the air during all the time necessary to acquire a volume fourteen or fifteen inches in circumference."

These two difficulties have already been fully explained. But the power of the theory does not stop here. It explains all the showers of dust, and rains of blood, (which are only water holding clay in solution) of which we have a great many well authenticated accounts. For, when the vortex reaches down to the surface of the earth, it is able to carry up large quantities of earth, as will appear from the following extract: "On the 6th of July, 1822, at thirty-five minutes past one o'clock, P. M., in the plain of Ossonville, six leagues W. S. W. of St. Omer, and six leagues south east of Boulogne, clouds were seen coming from different directions, and uniting together rapidly over the plain; they soon formed but *one*, which covered the horizon. An instant after, they saw descend from this cloud a thick vapor, having the bluish color of sulphur in combustion; it formed an inverted cone, whose base was in the cloud. After it passed from that place, it was discovered that it had made an excavation in the earth, in the form of a basin, twenty or twenty-five feet in circumference, and three or four feet deep in the middle. After tearing down a barn, and some trees, it passed on, a distance of two leagues, without touching the earth, carrying with it large branches of trees, which it threw out to the right and left with much noise. Having then arrived at an elevated wood, it tore off the tops of many oaks, and carried them over the village of Vendome, situated at the foot of the hill, on the east side of the forest. In this commune, it tore up by the roots a large sycamore, and carried it six hundred yards. The meteor, during its whole course, was like a bullet, which strikes the earth, and rebounds, tearing up the earth in places, and from time to time throwing out from its centre globes of fire, and globes of sulphurous vapors, and branches of trees. In the village of Witcanestre, of forty houses, thirty-two were prostrated, with their walls all thrown outwards, and at Lambre, eighteen, chiefly built of bricks, were sapped to their foundations in the same extraordinary manner." Nothing is said of either hail or rain accompanying this meteor.

Another spout, almost exactly similar to this in violence, took place near Treves, on the afternoon of the 25th of June, 1829. Suddenly, from the middle of a black cloud, about 20° above the horizon, a luminous mass began to move in an opposite direction, and to tear it open violently. The cloud near the top very soon took the form of a chimney, from which escaped a smoke of whitish gray, mingled, at intervals, with jets of flame, and rising through several openings, with as much force (so several witnesses express themselves) as if it had been driven with great force by several bellows. It had not gone far, when a new meteor, as some thought, appeared in contact with the ground, nearly under the other, though a little behind, and producing great destruction.

One man, who was prostrated by the spout, affirms that there were two currents, in contrary directions. The path of the meteor was from ten to eighteen yards wide, as marked on the earth, and about twenty-one hundred yards long. It lasted about eighteen minutes, and, as seen at the distance of a mile and a half, it had the form of a serpent, of a hundred and forty feet long, with its head towards the N. N. E., and its tail opposite. It disappeared suddenly, and without explosion, and, almost immediately afterwards, hailstones of extraordinary size fell in the woods, to the N. N. W. of the place where the spout had passed. The sun did not appear during this whole time, and there was not a breath of air; at least, so several of the spectators affirm.

The various phenomena accompanying these two spouts seem to me to favor, in a most remarkable manner, the fact of upward motion; especially the manner in which the houses were prostrated by the first. Indeed, this latter phenomenon appears to me to be an *experimentum crucis*, — to prove that a lighter column of air was suddenly brought over the houses, thus prostrated; and by thus diminishing the pressure on the outside of the house, the elasticity of the air within produced an explosion, prostrating the walls outwards, and carrying off the roof.

An upward force which could carry off a large sycamore many hundred yards, must have been quite adequate to produce this effect, if it could be brought to act instantaneously, or even very suddenly, which, in the present case, the whole description of the phenomena induces me to believe was the fact. Now, the diminution of the weight of the column of air under a cloud of great perpendicular diameter, when the dew point is very high, may be shown to be so great that the barometer under that cloud would fall as much as it is known to do in the midst of great storms, and if it falls only one inch in a water-spout or tornado, the air would spout up with a velocity of two hundred and forty feet a second, and, on coming over a house suddenly, the pressure on the outside would be diminished half a pound to the square inch, and the air within would thus be able to explode any ordinary wall.

Windows, also, have been known to have been burst open outwards in this country, by a violent and narrow storm, attended with hail, even when the houses were not thrown down; but as this might sometimes occur when an open door might be directed to a horizontal current, it is not adduced here as proof positive that this effect was produced by an upward vortex. Nevertheless, as the same spout which burst out windows, also lifted up, and carried to a great distance, heavy materials, these facts may well be adduced as *favorable* to the theory. In one case, however, which may be considered very strong in favor of the theory, the roof was taken off from a barn, and the grain in the inside carried out at the top, without the walls being thrown down.

In the eighty-eighth volume of the Journal de Physique, page 274, is an account of a great many spouts, both by sea and land. One of these, in the south of France, unroofed eighty houses, dispersed through the country the sheaves of corn which it carried out of a barn, broke the doors and windows of a chateau, and tore up the pavement in the middle of a room, without deranging some piles of china ware in it.

71. No one can doubt that the hail which fell almost immediately after the passage of the spout, was connected in some way with the spout itself. The manner of its connexion is fully explained by the theory. And even the perfect calm which reigned a short distance beyond the borders of the spout, which, in this instance, was very narrow, may easily be imagined from the outspreading of the air above, causing an increased pressure on the barometer, and thus preventing the air, beyond a certain distance, from moving towards the spout at the surface of the earth, and beyond this point even causing it to move in an opposite direction.

72. The direction, also, in which the latter spout leaned, may also be accounted for on supposition that the upper part of it reached the current of air which, in higher regions of the atmosphere, is always moving from the south west to the north east; for, as soon as it reached that current, its upper part would be blown in that direction, and the spout itself would have to move in that direction with it. Moreover, the spout would be stationary, if it was formed in still air, until its upper part should reach this upper current, which might be twenty or thirty seconds, and this will account for the excavation of the earth under the place where the spout was seen to be formed.

73. Again, the theory will account for the rebounding of the spout — that is, of its sometimes reaching the surface of the earth, and sometimes not. For, where the dew point was very near the temperature of the air, *there* a very slight rarefaction of air would produce cold enough to cause a condensation of the vapor, and so the vortex, with its condensed vapor, would be seen to reach the earth, and vice versa, where the dew point should be many degrees below the temperature of the air.

On the principles established in the first section, (22), the spout, which is nothing but visible condensed vapor, may sometimes not reach entirely down to the surface of the earth or sea, when the dew point is too low for such an effect; in this case, it will appear as an inverted cone, reaching down from a cloud already formed.

It may here be observed, that a spout will always begin to be formed at a considerable elevation above the surface of the earth, because the vapor will always begin to condense there, from a law too well understood by meteorologists to need elucidation here. When, however, it begins to condense, it begins, also, by its diminished specific gravity, to rise, and then, if all circumstances are favorable, the cloud will increase as it ascends, and finally become of so great perpendicular depth, that, by its less specific gravity, the air below it, and contiguous to it, in consequence of diminished pressure, will so expand, and cool by expansion, as to condense the vapor in it; and then the air below this again, will, in its turn, experience a greater and greater expansion and refrigeration, and, consequently, condensation of vapor; and this process may go on so rapidly, that the visible cone may appear to descend to the surface of the sea, or earth, from the place where it first appears, in about one or two seconds.

The terms here employed must not be understood to mean that the vapor, or cloud, actually descends; it appears, to the spectator, to descend, but this is an optical deception, arising from new portions of invisible vapor constantly becoming condensed, while, all the time, the individual particles are in rapid motion upwards.

74. For the sake of illustrating the principle, without aiming at absolute numerical accuracy, let us suppose a dew point ten degrees below the temperature of the air. Now, a diminished pressure of one pound to the square inch, will cause a fall of temperature of about seven and half degrees, so that, in this case, the visible cone would not reach down to the

surface of the earth, or sea, and the air would have to ascend a little more than three hundred yards, before condensation would commence. I say *more* than three hundred, because, though the temperature sinks one degree for every hundred yards of elevation, the dew point also sinks a little from the expansion of the air, and the same quantity of vapor occupying a larger space. But, if the dew point in the above case had been only six degrees below the temperature of the air, then the spout, or visible cone of vapor, would have reached the earth.

Now, it is highly probable that a spout, in passing over the surface of the earth, would meet with slight variations in the dew point, and, if so, it would rise as the dew point fell, and fall as the dew point rose; and thus the theoretical deductions correspond exactly with the facts.

75. Again, the direction of the two spouts, as also of the great storm with two veins of hail, mentioned before, was from the south west to the north east; and Pouillet says, that a large majority of these storms are known to move in this direction. I presume he means those which occur in France. Now, it is manifest that these storms, according to the theory, must move in the direction of the upper current into which they may ascend, for the top of the vortex will lean in that direction; and as theory demonstrates, and observation agrees with that demonstration, that the uppermost current of air in the temperate zone moves constantly from the south of west, towards the north of east, this will satisfactorily account for the general tendency of these storms in that direction, all over the northern temperate zone, or, at least above lat. 30°. For, from that latitude, down to the tropic of Cancer, the uppermost current of air moves nearly towards the north, and, within the tropic, it moves towards the north west; and so the theory would lead us to presume that, in these regions, the storms will be found to move in these directions. Such

is shown to be the fact by Mr. Redfield, as to all great storms which travel any considerable distance in the West Indies. And in the Philosophical Transactions, Lathrop'sAbridgment, volume 2, page 107, it is said that hurricanes in the West Indies begin from the north west, and terminate with a south east wind.

76. It is quite reasonable to suppose that these spouts sometimes meet with a middle current, moving in a different direction from the uppermost, which will account for the exceptions to the general rule; for the spouts will, in such case, certainly lean, and, of course, move in the direction of the middle current.

77. These three storms all occurred in the day, and two of them in the afternoon; and M. Pouillet says that many more occur in the day than in the night. Now, this is precisely what the theory would lead us to suppose, and the explanation of this fact affords me an opportunity of explaining the very commencement of those spouts which occur during the day. The sun, during the day, and especially in the afternoon, heats up the surface of the earth, and the air in contact with that surface, many degrees above the air, a few hundred feet above the earth. This heated air below, and cold air above, will form an unstable equilibrium, and a very slight agitation will cause to be formed upward vortices of the light air below. Now, if the dew point is not more than ten degrees below the temperature of the air in contact with the soil, the air of the upward vortex will not ascend much above one thousand yards, before the refrigeration, caused by expansion, will cause a beginning of condensation of vapor; and the moment this occurs, the velocity of upward motion is rapidly increased, from the expanding effect caused by the evolution of latent caloric, as before explained.

If the dew point of the air at this elevation should be almost identical with its temperature, the cloud of the upward vortex will go on increasing in size and perpendicular height, until the air immediately below it, being pressed downwards with less and less weight as the cloud above increases in height and levity, will, by expanding more than the air which preceded it in the vortex, be cooled down to the point of deposition, before it reaches the elevation of one thousand yards. And if, in this case, the column should rise to a height sufficient to produce a diminution of pressure under it of one pound to the square inch, the cone of visible vapor, or cloud, will reach down to a point four hundred yards from the earth's surface. And, in general, the nearer the dew point is to the temperature of the air, the lower will the visible spout descend ; so that, if they had been assumed only six degrees apart, in the above case, the apex of the spout would have descended to the earth. And, if they had been assumed still nearer together, the spout would not only have descended to the earth, but it would have been of some considerable size there. Thus we find that this mode of calculation not only enables us to account for the more frequent appearance of these spouts in the day than in the night, but also to assign a reasonable, hypothetical cause, why these spouts, or storms, are sometimes broad, and sometimes narrow, and sometimes even do not reach down to the surface of the earth.

78. It is known, also, that spouts, and violent storms, are always preceded by calms. The fact, also, is easily explained by the theory. For, in the first place, it is known that a calm favors the production of a high dew point, which is an essential ingredient in these storms; and, second, a vortex of great strength cannot be formed, unless it can rise nearly perpendicular to a great elevation, which never can happen where there is a strong wind. This will readily be admitted, when it is considered that the wind is always stronger at some distance above the surface of the earth, than at the surface itself; and, therefore, no vortex of any

great height, in these circumstances, could be formed, for the upper part would be blown away from the lower.

79. I have frequently seen those large columnar clouds, which form in mid air during a warm summer's day, have their tops blown off by an upper current, when the lower air was almost still, and thus a vortex of great strength prevented from forming. That these clouds are actually formed by rising vortices, occasioned by the disturbance of the equilibrium of the air during the day, is rendered almost certain by the following facts. First. When the supply is cut off in the evening, by the air near the surface of the earth becoming cold, these clouds cease to form, and not unfrequently disappear, and a day with many clouds is followed by a cloudless night. On the supposition of upward vortices, this phenomenon is very simple and natural; but on any other supposition, it is utterly paradoxical, (especially when it is now known that depression of temperature is the only cause of the condensation of aqueous vapor,) how clouds can be formed under a meridian sun, which will be dissipated under the refrigerating influences of a nocturnal sky.

Second. I once saw, during a profound calm, those columnar clouds, in all parts of the heavens, appear to be coming slowly towards me, which I think can only be accounted for by supposing that they were all rising perpendicularly. These clouds, however, were gradually dissipated after they had increased to a considerable size, which proves beyond doubt that they were surrounded by air, at that elevation, whose dew point was below the temperature of the air; and it may be added, that this is one of the cases where a spout cannot be formed, for the ascending air of the vortex will always, more or less, be mingled with the air through which it passes.

Again, nothing but an upward or a downward vortex will account for the well known fact, that, in these storms, the clouds are frequently seen to rush together with great rapidity, for some time, without overlapping each other, and crossing, which proves that they are on the same horizontal plane, and so demonstrates the existence of a vortex. I need hardly add, that other phenomena show that the motion, after meeting, is upwards, and not downwards.

80. Clouds have also frequently been seen to ascend, by spectators on mountains, and aeronauts have found their temperature much higher than the surrounding air. Thus, it is demonstrated, beyond all doubt, that there is an upward current in these storms, whether the latent caloric given out by the condensation of the vapor, is the cause of that current, or not. And, as no fact in physics is better established than that precipitation will instantly take place, if saturated air is suddenly rarefied, we are sure, also, that this upward motion of saturated air will, by causing expansion, produce precipitation.

81. I had long been desirous to ascertain, by actual observation, how high these vortices carry the condensed vapor, or cloud, into the upper air, and a fine opportunity was afforded me, on the 31st of July, 1834. This morning, says my journal of that day, " it began to rain early, with the wind and lower clouds north east, middle clouds south, and upper clouds west." Several showers occurred during the morning, and the wind gradually shifted round to the south east. About five o'clock, P. M., a most violent shower, which lasted about fifteen minutes, came up from the north west, and at the moment of the hardest rain, the lower wind being strong from the north west, the lowest visible clouds in a south east direction, were seen to move with great velocity in the opposite direction, towards the north west.

As soon, however, as the shower passed off to the south east, the lower clouds changed their course, and followed the shower towards the south east, exposing to view, near the zenith, a most magnificent columnar cloud, with its summit and western side as white as snow, being exposed to a western sun, in a perfectly clear sky. This cloud seemed nearly stationary for some time in its upper snowy part, while the scattering clouds in its lower parts were seen to rush under it, towards the south east, with great velocity. The principal cloud moved slowly and majestically towards the E. S. E.; the sun's rays gradually climbing up this mountain of snow, fourteen minutes after he set, his last beams ceased to illuminate its summit.

The altitude of this summit being taken by a sextant, was found to be nine and a half degrees. The line which bounded light and darkness as it rose up the sides of this columnar cloud, was well defined, the western horizon being entirely free from clouds, so that I think I could not be mistaken one quarter of a minute in the time when the sun's rays ceased to shine on the top of the cloud. Calculating from these data, I find the cloud reached to the amazing height of ten miles, and that it travelled E. S. E. with a velocity of about forty-five miles an hour."

A much more violent storm than this had occurred at Wilmington, (Del.) about twenty-eight miles south west of Philadelphia, two days before this, as appears from Dr. Gibbon's Journal. He says it commenced raining with a thunder gust, at five o'clock in the morning, and poured down in torrents till half past seven, when it ceased. In this short time, two and half hours, five and one-tenth inches of water fell. This rain, he says, did not extend further than ten or fifteen miles from Wilmington, in any direction, except, perhaps, in an easterly course, in New Jersey.

On that evening, my journal says, "The upper clouds from the W. S. W. were tinged with pink, thirty-one minutes after seven o'clock, mean time." These clouds, being in the zenith, must have been the astonishing height of fourteen miles, if no allowance is made for the refraction of light.

The angular velocity of one of these upper clouds was taken; it was found to rise from 25° to 32°, in two and a half minutes. Its absolute velocity, therefore, at this great height, was nearly two miles a minute. This great velocity is not at all inconsistent with the velocity with which storms are known generally to travel towards the north east, in our latitude, even on supposition that this direction is given to the upward vortices of these storms, by this uppermost current, as explained before; for the inertia of the air in the vortices must be overcome, and, therefore, the velocity of the storm, at least the hinder part of it, cannot be so great as the velocity of this uppermost current.

82. There are many well authenticated accounts of showers of dust, and bloody, or, as I imagine, reddish rain, having fallen, and also of hail, with earthy or stony matter contained in the stones, and some with green leaves of forest trees; all these facts are mere corollaries from the theory. Professor Zimmerman analyzed the sediment of some red rain which fell on the 3d of May, 1821, near Geissen, and found it to contain chrome, oxide of iron, silex, lime, carbon, and a trace of magnesia, but no nickel. On the 13th of August, 1824, in the city of Mendoza, in Buenos Ayres, dust fell from a black cloud, and at the same time, in another place, distant forty leagues, the same phenomenon occurred.

In Persia, near Mount Ararat, there fell, in the month of April, 1827, a shower of *seeds*, which, in some places, covered the earth to the depth of six inches. The sheep ate of it, and men made a tolerable bread of it. The French ambassador in Russia obtained some specimens of this grain, and sent them to Paris, where they were analyzed and examined by MM. Desfontaines and Thenard, and determined to be lichens of the genus Lecidea.

Now, as neither leaves of forest trees, nor seeds of lichens, can grow in the upper regions of the atmosphere, or be precipitated to the earth from any other planet, if these accounts are believed, and M. Pouillet doubts not the truth of them, then the existence of upward vortices, however these vortices may be formed, is established. — (Pouillet, page 770.)[1]

83. The theory will also account for the water spout. Indeed, a spout at sea, and a spout on land, are identically the same thing, and many have been known to pass from water to land, exhibiting the same appearance in both situations. To show their identity, I will copy from Silliman's

[1] See Records of Gen. Sci. vol. 4, page 157, for an account of a shower of frogs, three or four layers deep, which fell near Toulouse, described by Professor Pontus. See also Athenæum, for October, 1840, for the following account, communicated to the British Association.

Colonel Sykes communicated the contents of a leter from India, from captain Aston, one of the diplomatic agents of the government of Bombay, in Kattywar, on the subject of a recent singular shower of grain. He stated that full sixty or seventy years ago, a fall of fish, during a storm in the Madras Presidency, had occurred. The fact is recorded by Major Harriott, in his "Struggles through Life,' as having taken place while the troops were on the line of march, and some of the fish having fallen upon the hats of the European troops, they were collected and made into a curry for the general. This fact for probably fifty years was looked upon as a traveller's tale, but, within the last ten years so many instances have been witnessed and publicly attested, that the singular anomaly is no longer doubted. The matter to which he had to call the attention of the section, was not to a fall of fish, but to an equally remarkable circumstance, a shower of grain. This took place on the 24th of March, 1840, at Rajket, in Kattywar, during one of those thunder storms, to which that month is subject; and it was found that the grain had not only fallen upon the town, but upon a considerable extent of country and round the town. Captain Aston collected a quantity of the seed, and transmitted it to Colonel Sykes. The natives flocked to Captain Aston, to ask for his opinion of this phenomenon; for not only did the heavens raining grain upon them excite terror, but the omen was aggravated by the fact that the seed was not one of the cultivated grains of the country, but was entirely unknown to them. The genus and species was not immediately recognizable by some botanists of the Section D., to whom it was shown, but it was thought to be either a spartium or a vicia. A similar force to that which elevates fish into the air, no doubt operated on this occasion, and this new fact corroborates the phenomena, the effects of which had been previously witnessed.

Journal, volume 14, page 171, an account of a water spout seen off the coast of Florida, in the spring of 1826, by Benjamin Lincoln, M. D., of Boston.

"April 5th. At six o'clock, A. M., an order was heard from the deck to get ready the gun on the weather quarter, and bring the muskets from the cabin. Recollecting what region we were in, my first thought was of an engagement with a piratical cruiser, but on going upon deck, it appeared that our enemy was a water spout, bearing north, distant, according to the captain's estimation, about two miles, and coming down upon us before a wholesail breeze. One musket was fired at it, but it had nearly effected a retreat before we got ready for action. I had just time to see it, and it disappeared.

"In a few minutes another appeared, which was said by the officers of the vessel to be much more distinct than any one they had ever seen before. I observed it attentively, but neglected to note the time, except at its commencement, and the end of the third spout, which appeared after the second and principal one had passed away. This omission renders it impossible to give the duration of its different stages with any good degree of exactness. The wind came from the land, blowing a wholesail breeze. The thermometer stood at 72°. A black cloud, from which the spout proceeded, extended along from east to west, its lower edge very distinctly defined, even, parallel to the surface of the water, and elevated 25° or 30° above the horizon. No other cloud was visible in that quarter, but a haziness covered the whole heavens.

"A small, black, and perfectly defined cone, darted from the lower edge of the cloud, and pointed perpendicularly to the water, which, at the same moment, was seen flying upwards like spray on the rocks. It was distinctly noticed that the cloud grew blacker near the cone, appearing to be gathered in from all quarters, and condensed at this point.

"After the lapse of two or three minutes, the cone instantaneously extended itself to about twice its first length, and the water was thrown up higher. This continued a few minutes; then the apex of the cone suddenly leaving the truncated end jagged, from which little cirri were continually darting and disappearing, the water continuing as before. This appearance lasted two or three minutes, after which the cone gradually elongated itself, assumed the cylindrical shape, except near its junction with the rest of the cloud, and descended almost to the surface of the water. The time occupied by the descent was about two seconds. All these changes were instantaneous, except the descent, which was gradual. As the spout descended, the agitation of the water increased, boiling up on each side of the end of the spout, but not coming in contact with it. The spout was slightly curved, the convexity of the curve being towards the point whence the wind came. It appeared to be hollow, light in the middle, and black, like the cloud, at its sides. A waving, ascending motion, was distinctly seen in the middle, more distinctly near the water than near the cloud. This the sailors, with one accord, pronounced to be water going up the spout.

"This appearance lasted fifteen minutes, or more, the spout remaining entire and unchanged. Then it began to fade, and suddenly a section from its lower end disappeared, leaving the same cirrous jagged extremity before mentioned. One section after another disappeared in this way, the spout continuing to grow paler, the waving motion growing more distinct and slow, and the agitation of the water subsiding, till the whole disappeared. By this time, the wind had freshened considerably, and the cloud had spread over a great part of the heavens. In a few minutes after, another cone appeared, exactly like the first in all respects, and the same appearance was exhibited in the water under it. This continued a short time, and then disappeared.

"From the appearance of the first cone, till the disappearance of the last, was three quarters of an hour.

"The wind continued to increase, and the cloud to gather in blackness, and spread in every direction, till it enveloped the whole heavens. Next came a most vivid flash of lightning, with a most tremendous peal of thunder. It seemed as if heaven and earth had exploded at once, and in an instant all was calm, the sails hung loose, and not a breath of wind could be felt. Rain now began to fall, not in drops, but in torrents, and the wind came in gusts from every point of the compass. It continued to rain and blow in this way about fifteen minutes, after which it ceased, the wind in its former direction, the sky became clear, and we went on our way."

If any one will carefully examine the phenomena here described, and compare them with the two land spouts described above, he will perceive their exact similarity in all the most important features, — the gathering in of the clouds at the upper end of the spout, where it lost itself in the cloud; the inverted cone of thick vapor descending; the commotion of the water, and the removal of the earth under the spout, and, above all, the rain that occurred after the termination of the spout.

It is worthy, also, of particular remark, that the rain lasted exactly the same length of time that the principal spout lasted, fifteen minutes, and probably it commenced thirty minutes after the spout, or fifteen minutes after its disappearance. And as this rain and the spout were undoubtedly parts of the same phenomenon, and if, according to the theory, the rain was condensed in the spout, and carried up by the spout, we are led to believe it must have been carried up a great distance, or it would not have taken thirty minutes to ascend and descend. It is true, that, in ascending, it would move upwards much slower than the vortex of air which carried it, for the drops would gradually increase in size in their upward motion, by the finer particles of condensed vapor constantly overtaking them in their course, and uniting with them, until, by their increasing size, and the diminishing force of the air, from its diminishing density, they would stop their upward motion, and be thrown off at the sides of the vortex, as explained before.

It is worthy of remark, also, that the suddenness with which "the cloud gathered blackness, and spread in every direction, till it enveloped the whole heavens," is easily and naturally accounted for by the outward motion of the vortex above, as explained in a preceding part of this section, Even the direction in which the spout leaned, from the wind, could have been predicted from the theory.

84. In the Edinburgh Philosophical Journal, volumes 5 and 6, are given descriptions and plates of water spouts, which appear to me almost to demonstrate, of themselves, the theory here advanced. Several of these spouts were attended with rain, at the distance of about a quarter of a mile from the spout, and they all began to descend from the cloud in the form of an inverted cone, that gradually proceeded downwards to meet a smokelike appearance, which rose from the surface of the water to meet it.

This cone was black at first, but, towards the end, it began to appear like a hollow canal ; the sea water could, even while it was entirely black, be seen very distinctly flying up along the middle of it, as smoke does up a chimney, with great swiftness; and the wind, in all instances where mentioned, blew towards the spout below. These phenomena, with the exception of the hollow canal, have already been explained.

In the fourth volume of the Abridgment of the Transactions of the Royal Society of London, a description of many other spouts is given, attended with circumstances similar to those already described. One of these occurred in England, on the 3d of June, 1718. "It was stationary for a length of time not mentioned, and discharged an immense quantity of water, without thunder. It fell on a space about sixty feet over, and tore up the ground there seven feet deep to the rock, and made a deep gulf for about half a mile from that place, raising a stream below, so as to render it impassable." All this must have occurred in a few minutes, as, immediately on the appearance of the spout, some persons attempted to run home, but they found the brook already impassable.

By having deferred the publication of these essays so long, I am now enabled to refer to a highly interesting account of some water spouts, seen by Lieut. H. W. Ogden, and communicated in the January number of Silliman's Journal.[1]

It was in May, 1820, in the edge of the Gulf stream, the weather being very warm, and the atmosphere close and oppressive, when seven were seen in the course of half an hour, varying, in their distance from the ship, from two hundred yards to two miles. Lieut. Ogden says: "The atmosphere was filled with low, ashy-colored clouds, some of which were darker underneath than others, and from these the water spouts were generally formed, each one from a separate cloud. In some instances, they were perfectly formed before we observed them, but, in others, we could see a small portion of the cloud, at first extend downwards, in the shape of an inverted cone, and then continue to descend, not very rapidly, until it reached the water. In other instances, however, we observed that this conical appearance of a portion of the cloud did not always result in the perfect formation of a water spout. Several times we saw the cone project, continue for a short time stationary, then rise again slowly, and disappear in the clouds. This would, in some cases, occur two or three times to the same

[1] See also Naval Magazine, No. 1, vol. 1.

cloud; but, eventually, a larger and darker cloud would descend, and result in forming the visible spout, as above mentioned."

One spout passed within sixty yards of the ship, and, after having been visible more than twenty minutes, at the distance of about three hundred yards, its lower part became smaller, and then gradually rose, until entirely lost in the cloud, part of which still hung over them. Soon after this, several severe flashes of lightning struck near the ship, and the rain began to fall in large and very *cold* drops, perfectly *fresh.*

85. I come now to a most important part of this investigation, the north east storms of the Atlantic States. It is well known, since the days of Franklin, that these storms commence in the south west, and travel towards the north east with a velocity which varies at different times and places, and that the wind always blows from some eastern point at the commencement of the storm.

Mr. Redfield, of New York, has collected a great many highly interesting facts connected with these storms, of which some of the most important shall now be detailed.

"When a storm commences within the torrid zone, it travels west of north until it reaches lat. 30°, when it has become nearly north; it then gradually deflects more and more east of north, until about lat. 40°, it is moving about north east.[1] That these storms are probably nearly round, varying in diameter, and more slow in their advance along the coast, in proportion to their size, and also slower in low latitudes than in high." I have found that, on their north western side, the wind sets in more northerly and changes round during the storm by north, and on the south east side of the storm the wind sets in at the commencement more easterly and south easterly, and changes round by the south, on the coast of the United States.

[1] Perhaps to the east, or south of east.

Mr. Redfield thinks that these facts can only be accounted for on the supposition, that these storms are exhibited in the form of great whirlwinds.

As a more particular proof of this position, he details the facts which occurred in Connecticut, as one of these storms passed there in 1821. He says "that the mass of atmosphere upon the earth's surface was moving for several hours, apparently towards the north west, over Middletown, with a probable velocity of seventy-five or one hundred miles per hour, while in the northern parts of Litchfield county, at a distance say of forty miles, the wind, at about the same period, was blowing with nearly equal violence in the opposite direction," towards Middletown. Now, it will appear by a little reflection, that all these facts agree with the idea of an upward vortex, more consistently than with a horizontal whirlwind.

Indeed, I do not hesitate to say, that the last fact is inconsistent with a horizontal whirlwind, and proves, with irresistible evidence, the existence of an upward vortex, at least in this storm. For two winds cannot blow towards each other for several hours as here described, without either rising upwards when they meet, or blowing outwards at the sides. But we have proof positive, that they did not blow outwards at the sides, for at New York, south west of the point between Middletown and Litchfield, to which the winds from those places were blowing, the wind changed round by the north to the north west, or west, about the time these winds began to blow violently. And we have strong reason to believe that it did not blow outwards to the north east, for, at the commencement of the storm, through its whole course, the wind always blew from some eastern point.

There is one conclusion which Mr. Redfield draws, which I do not find to be justified by facts detailed in this storm. "That along the central portion of the track, the storm was violent from the south eastern quarter, *changing suddenly* *to an opposite direction.*" Now I find that, of fifteen points on the south east side of the storm, at which the wind set in south of east, only two — Bridgeport, Connecticut, and one at sea, forty miles north of Cape Henry — are given, as having the wind to change round, even as far as the west. These two I *suspected* as being contrary to my theory; and, upon examination of the newspapers of the day, I find that they report the wind at both these places to have changed round only to the south west, just as far as it *should* change to satisfy my theory.

All these facts lead to the conclusion that in this storm, at least the wind in the neighborhood of the storm, blew directly towards its centre, and if so, it follows, beyond all doubt, that there was an upward motion in the middle of the storm. Now, as it is impossible to conceive of an upward vortex being formed in the region of the storm, if there is a condensation of air there, so it can only continue on the supposition that the air, as fast as it arrives in the vortex from all sides, becomes rarefied, whatever may be the cause of that rarefaction.

86. As it has been said that a condensation in the region of the storm would cause an afflux of air there, let us for a moment examine the assertion. Suppose that no latent caloric is given out in the condensation of vapor, and that in a circular space of one hundred miles in diameter, five inches of rain have fallen, the whole condensation which would take place by the change of vapor to water, would be less than a fiftieth of the whole atmosphere, and the air on all sides of the storm, would not have to move one mile towards the centre, before the equilibrium would be restored. Besides, it is manifest that this motion could not take place at the surface of the earth, but rather in the region of the cloud and above it. And even if the velocity at the surface of the earth is supposed to be as great as in the region of the cloud, it could not be a mile an hour, for

it never has been known to rain five inches an hour in a storm of this magnitude, and the condensation of the air is supposed to take place during the whole rain.

87. I have myself had the pleasure of seeing and pointing out to many of my friends at various times, the clouds moving outwards above, and inwards below, during a summer's thunder gust, which could not be, if there was a condensation of air in the region of the cloud, and I may add, without the fear of contradiction, that it proves the reverse. Besides, I have known many instances of long continued and violent rains in the south, during the prevalence of a strong and long continued north wind, and of long continued and violent rains in the north, during the strong and long continued south wind.

An instance of the latter occurred on the 11th, 12th, 13th, 14th, and 15th of May, 1833. In my journal it is stated that a strong south wind prevailed during this whole period night and day. And by consulting the papers of the period, I find the following facts:

Harrisburg, May 16, 1833. When our paper went to press, the Susquehannah was sixteen feet above low water mark, and rising — a greater freshet than has taken place for sixteen years — the rain must have been much greater up the river than in the vicinity.

Albany, 15*th.* The most painful accounts begin to be received of the destructive effects of the freshet. The river continued to rise until ten o'clock this morning, when it was a foot higher than it was in the great freshet occasioned by the ice in the spring. On the 17th, it had fallen only a few inches.

The *Amsterdam* (Mohawk Herald) of the 16th, says, "every bridge and mill dam on the creek near Fort Johnson has been swept away."

Hartford, 18*th.* The water in the Connecticut last evening, was 19½ feet above low water mark.

Montreal, *May* 15*th*. A larger quantity of rain has fallen here since midnight of last Friday, (five days,) than we have had for a considerable period past, and the rain is now falling in torrents, the atmosphere cool and very unpleasant.

The *Goshen* Patriot says, the Delaware rose twelve feet above an ordinary freshet—not a raft above Milford was preserved entire.

These facts afford conclusive evidence that, in this case at least, the wind at Philadelphia blew hard for five days, exactly towards one of the greatest rains which our country has ever witnessed. And the statement, that the atmosphere at *Montreal* was cool and very unpleasant, would lead us to suppose that the wind there was coming from some northern quarter; for, during this whole period, the temperature was very high in Philadelphia, the mean minimum being 65°, and the mean maximum 76°, and if a southern wind prevailed there, it is not at all likely that the air would have been cool and unpleasant.

Again, from the 3d of June, 1835, to the 12th of the same month, the wind was constantly from the north, with one exception from north east, pretty strong for a considerable portion of time.

I find by the *Charleston* Courier, that a dreadful storm of rain set in there on the 3d, and another very violent one on the 8th, which was increasing when the paper went to press on the 9th at 10 P. M., and that on that day there had been no mail from Fayetteville, and that there were six letter mails due from New York and Boston, and five from Washington, Baltimore, and Philadelphia.

All these facts seem utterly at variance with a horizontal whirlwind; and entirely consistent with an upward vortex, if they do not absolutely prove one.

88. If Mr. Redfield should perceive that all the interesting facts which he has with such laudable industry collected,

are fully explained by a theory which accounts also for the rain, I am sure he will not be very tenacious of his horizontal whirlwind; especially when he does not pretend to show that either the whirlwind is the cause of the rain, or the rain the cause of the whirlwind. Let us, however, examine for a moment (for I should be proud to enlist Mr. Redfield under the banners of a true theory) what would be the phenomena, on the supposition that there is a horizontal whirlwind, say of one hundred miles in diameter, moving with a velocity of seventy-five miles an hour, or one hundred and ten feet per second. It is demonstrated in mechanics, that if a body moves in a circle, with a diameter of sixteen feet, and a velocity of sixteen feet per second, its centrifugal force will be equal to its gravity. And as centrifugal force is directly as the square of the velocity, and inversely as the radius, the centrifugal force of the air in this whirlwind is ascertained by the following proportion:

$\frac{16^2}{16} : 1$ (gravity) $:: \frac{110^2}{25 \times 5280} : \frac{1}{74}$ or $\frac{1}{74}$th part of the gravity.

And as a wedge of air fifty miles long is about eight times as heavy as a column of atmosphere equal to its base, its whole centrifugal force will be $8 \times \frac{1}{74}$ of fifteen pounds to the square inch, which would cause the barometer to rise about $1\frac{4}{10}$ of an inch in the borders of the storm, both at its commencement and termination; and cause a motion of the air outwards due to this pressure, which would be about two hundred and eighty feet per second, according to the principles of spouting fluids. Now these two phenomena are entirely wanting in all north east storms; for the air does not blow outwards from the storm, nor does the barometer rise at the termination above the mean, though it sometimes does at the commencement, for a reason which shall hereafter be explained. Besides, if such a whirlwind could be generated, it is manifest that it would soon be destroyed by its outward motion, unless some mighty cause exists, of which we have no knowledge, to generate new motion in the air, which would descend from the upper regions of the atmosphere in the middle of the whirlwind, to take the place of that which had thrust itself out by its centrifugal force. It may be added, that the readiness and ease with which the air would descend in this whirlwind, would be so great that the rarefaction of the air in the inside, caused by the centrifugal force of the air would be a quantity very minute, unless we suppose the whirlwind to reach to a great height, which cannot be the case, if it is produced by friction on the West India Islands, and on our coast, as is alleged by Mr. Redfield.

Therefore, it will not account for the great fall which is known to take place in the barometer, during these violent storms, a fact which is fully explained by the theory here proposed. Besides, Mr. Redfield need not be told that this downward motion of the air in the centre of the whirlwind, would increase its capacity for vapor, and effectually prevent deposition, or formation of cloud.

89. If all other proofs were wanting, our great north east storms of six or eight hundred miles in diameter, from north east to south west, and of unknown extent from south east to north west, would afford us an undeniable proof of an upward current. These storms always set in from near the north east, and terminate near the west. So we have proof positive, that the wind, near the surface of the earth, is always blowing both east and west of the storm towards the storm itself. I have observed these storms for many years, and I have never known but two to terminate with the wind from the eastern quarter, and then the anomaly was soon explained in both instances, by another storm coming on in less than forty-eight hours. But even in these cases, after the termination of the first storm, the wind was very gentle, nearly calm.

The wind always commences from the north east, some hours (from ten to forty) before the beginning of the rain or snow, and does not change till near the end: however, it is believed that the upper clouds, during all this time, continue to come from the south west.

They certainly do so till they are concealed from view by the lower clouds, which generally form a short time before it begins to rain, and the moment the lower clouds break away a little, near the end of the storm, the upper clouds are seen moving in the same direction. Besides, I have more than once got a peep through the lower clouds, during the progress of a storm, and discovered thick, dense clouds above, coming from the south west.

I have also seen instances of a strong wind at the surface, directly opposite to the motion of dense clouds above, which were evidently not very high, from their great velocity, and I afterwards learned that at the same moment there was a very great rain about one hundred miles distant, in the direction towards which the lower wind was blowing. The extent, however, of these rains, I did not learn. It must depend upon future and more extended observations, to learn whether the outward motion of the air in the upper part of the vortex, extends beyond the boundary to which the inward motion of the air below reaches.

90. On the ocean, it is known that these storms are attended with immense swells, reaching beyond the agitation of the atmosphere. This effect is probably much more dependent on the diminished pressure of the atmosphere on the ocean under the vortex, than on its horizontal velocity. For a fall of three inches in the barometer will cause a rise of the water of more than three feet to produce equilibrium, and as the waters would move in all directions towards the point of least pressure, their momentum would cause a rise two or three times this quantity independent of the effect caused by the friction of the air. How far the reciprocation of this wave would extend I am not at able to say. I

have read of considerable elevations of the water, at one end of the lake of Geneva, which were evidently not produced by the wind blowing over the surface of the lake in a direction favorable to such an elevation; if there was a spout passing, near the time of the elevation, it would account for the phenomenon. Indeed, if the spout should even pass over the middle of the lake, and the barometer should fall there three inches, it would cause such a swell that its reciprocations would reach its extremities after the spout had passed away, and thus these swells would appear to take place in the midst of a calm, and so be apparently unconnected with the wind. Mr. Dalton informs us that "the surface of Lake Derwent is sometimes agitated, when no wind can be perceived, in so violent a manner, that it exhibits large waves with white breakers. The phenomenon is called a bottom wind; but the cause of it is utterly unknown." Lake Wetter, in Sweden, is affected in a similar manner.[1] The theory of upward vortices shows how such an effect might be produced.

91. Even as to the barometer itself, I have not seen any theory which is able satisfactorily to account for its great and sudden falls. It cannot be the diminished pressure which takes place from the deposition of rain, for if ten inches of rain were to fall so suddenly that the air would not have time to rush in and restore the equilibrium, it would not cause the barometer to fall one inch.

Indeed, so great has been the difficulty on this point, that the author of the art. Physical Geography, in the Edinburgh Encylopædia, thinks these depressions are caused by the destruction of large portions of the air in the higher regions of the atmosphere by electricity acting on the combustibles which ascend there from the earth. I need hardly add that this phenomenon is a corollary from the theory here advanced.

[1] Ed. Ency., art. Physical Geography.

92. It has been thought, also, that the centrifugal force of the wind blowing over the curvature of the earth's surface, might cause these great depressions of the barometer. But if we suppose the whole of the air in motion with a velocity of one hundred miles an hour, and calculate its centrifugal force according to the principles laid down before, its gravity would be diminished, when the wind was west, only about one hundred thousandth of its whole weight, which would cause the barometer to fall .0003 of an inch; and if the wind is east, it will readily be perceived that its gravity will be increased to the same amount. The theory will also account for the great depression of the barometer, which is known sometimes to accompany the action of volcanoes.

93. On the 19th of December, 1821, a violent eruption commenced from the old volcano Eyaf jeld Jokkul, in Iceland, which had been quiet since the year 1612. On the very day of the commencement of the eruption the waters of the rivers which descended from the surrounding mountains, were considerably increased. All over Europe dreadful storms of wind, hail and rain succeeded the commencement of this eruption. On the 24th, particularly, extraordinary devastations were experienced in very distant parts of Europe, and generally, wherever the hurricane appeared, deluges of rain accompanied it. At Genoa, and many other parts of Italy, the storm is described as particularly severe, (wind S. and S. E.,) many parts of the country and the roads being entirely submerged; and the next day, the 25th, the barometer fell unusually low all over Europe, including Great Britain. Now it is highly probable, that the eruption of the volcano threw out immense quantities of vapor, and if so, the condensation of this vapor would heat up the atmosphere by the evolution of its latent caloric, as was explained before, and this heated air would rise and spread out in all directions; and a vortex being thus established and kept up by the action of the volcano, both by

mechanical force and by a diminution of specific gravity, the air rolling out on all sides above, and pressing in on all sides below, a general rain would be the consequence, and this rain might spread out so far from the centre of action, as to reach even the south of Europe in five days. The barometer continued to fall, in Iceland, from the day before the appearance of the volcano, till the twenty-sixth day after it was at the lowest in different parts of Europe, and two days after the prevalence of great storms in Italy and France. During all this time the volcano was in active operation, and even as late as the 23d of February, it emitted smoke greatly resembling steam of boiling water. The whole quantity of rain which fell from the 19th till the 24th, must have been very great; for even as far south as Genoa, the air, for several days previous to the 24th, when the great tempest occurred there, "had been filled with thick vapors, which vented themselves in torrents of rain, and the wind blew from the south with intense violence." This south wind would bring from the Mediterranean an immense quantity of vapor, to be condensed when it entered into this vast upward vortex. Let us suppose then, what is certainly within bounds, that five inches on an average of rain, fell over the surface of Europe, from the 19th till the 24th, or the morning of the 25th; and in Paris, where the flood was not as great as in many other places, there fell 6.4 inches. From the principles explained before, the caloric given out by the vapor in condensing into rain, would heat the whole atmosphere 11.4° for every inch of rain, or in the present case 57.° And as the mean temperature of the air was certainly below 32° the expansion due to this increase of temperature would be more than $\frac{57}{480}$ of the whole, which would cause the air to stand at its surface five and a half miles higher over the region where the rain had been deposited, than in surrounding countries, provided it was forty-five miles high before the deposition, and none had flowed off.

This last supposition, however, cannot be true, for the moment it began to swell up by expansion, it would begin also to flow off, and the depression of the barometer would be in proportion to the quantity rolling off above, greater than that which ran in below towards the point of least pressure. This difference would be considerable for two reasons; first, the air below would not begin to run in until the air above had rolled out; for a mere expansion and swelling up of the air would not diminish its gravitation, and second, its resistance would be less from friction than the lower air would experience rubbing along the surface of the earth. Besides, its outward motion from the centre of the vortex, would not so much be a rolling down an inclined plane in consequence of its being swelled into a greater perpendicular height, as a shoving out of the surrounding air at an elevation of about three and a half miles and upwards, where the air in the vortex would overbalance the surrounding air, as will easily be conceived by any one who will consider the effect of an upheaving of the atmosphere by expansion. From all these causes facilitating the outward motion of the upper air in the vortex, it is probable that at least one half of the quantity of air elevated in the vortex above the surrounding air, by expansion, would flow off, and if so, it would cause a depression of the barometer, within the region of the rain, of more than one inch and a half. And this corresponds with the depressions given in many places.

This depression would cause a velocity of the air at the surface of the earth, on the outside of the vortex, towards the centre of rarefication, of one hundred and fourteen miles per hour, if there was no friction; but as the friction at the surface of the earth is very great, the velocity would probably not be more than one half this quantity, or fifty-seven miles per hour. This velocity would not be sufficient to produce the overflowing of the sea at Genoa, Leghorn and

Trieste, but if to the force of the wind, we add the diminished pressure of the air along the northern shore of the Mediterranean and the Adriatic, and the increase of the pressure of the air on the outside of the storm, by the rush of the air outwards above; the rise of waters, there might be quite sufficient to produce the disastrous effects which spread consternation over so much of the southern part of Europe.

Was the remarkably warm winter of 1821 and 1822, in all the north of Europe, caused by the immense quantity of latent caloric given out during these great rains, together with the southern winds which prevailed in consequence of the upward vortex of air over Iceland during this whole winter? At St. Petersburg, dreadful floods of rain repeatedly occurred during the winter, and the snow had entirely disappeared by the first of February; and even beyond Tobolsk, warm winds prevailed, and generally in the interior there was no snow. And on the 2d of March, the Dwina was free from ice at Riga.[1]

If this were the only fact on record, of rain accompanying volcanoes, it ought in this case, to be considered accidental and unconnected, but nothing is better established than the connexion of volcanoes with rains, from their very frequent concomitancy. Indeed, Baron Humboldt speaks of the mysterious connexion of volcanoes with rains, and adds, that they sometimes on breaking out change dry seasons into rainy in South America. This connexion will be considered mysterious no longer. It may here be added as a reason why volcanoes do not always produce rains, that in the most unfavorable state of the dew point, rains cannot be produced.

M. Lyell, in his Principles of Geology, vol. 2, page 94,

[1] See the Phil. Journals of 1822, which all seem to acknowledge that there was some connexion between the bursting out of this volcano and the rains which ensued.

says, "Aqueous vapors are evolved copiously from a crater during eruptions, and often for a long time subsequently to the discharge of scoria and lava. These vapors are condensed in the cold atmosphere surrounding the high volcanic peak, and heavy rains are thus caused in countries where, at the same season, and under ordinary circumstances, such a phenomenon is entirely unknown.

We learn from history, that a heavy shower of sand, pumice, and lapilli, sufficiently great to render Pompeii and Herculaneum uninhabitable, fell for eight successive days and nights, in the year 79, *accompanied by violent rains.*

94. Journal of Royal Institution, vol. 1, page 302. Rain and hail in an eruption of Vesuvius, on 25th March, 1828, are mentioned, and also on 5th July of same year. Quarterly Jour. of Sci. Lit. and the Arts, vol. 5, page 201. In an eruption of Vesuvius, on 25th December, 1817, there was a hail storm, accompanied with red sand. Jour. Sci. and Arts, vol. 19, page 230. A hail storm occurred during an irruption of Mount Ætna, 21st June, 1813. In vol. 20, page 358, G. Poulettsrope, in a work on volcanoes, says, It must be noticed, that from the action of the volcano on the atmosphere, clouds are generally formed in it, which produce falls of rain, often causing torrents, or even inundations.

95. If the reader will examine the writings of M. Du Carla in the Oserv. sur la Physique, he will find the most triumphant proofs of the influence both of mountains and volcanoes in forming clouds and rain. Indeed, the author goes so far as to say that the eternal rains in Northern Peru around the volcanoes there, which are always in blast, draw away the vapor from Southern Peru, and thus prevent it from raining there.

96. Cumuli or column clouds are formed in the following manner; air at the surface of the ground below becomes heated, as it always does in clear, calm days,

some degrees hotter than the air a little above the surface, and thus produces an unstable equilibrium, so that the least agitation would cause an upward motion to commence at the point of greatest heat, especially if that point contained a higher dew point, as it generally does. As soon as this motion commences, other air rushes in below, and the higher and longer the column of heated air becomes, the more rapid does the upward motion become, and finally, after the upper end of the column is as many hundred yards high as the temperature of the air on the ground is above the dew point in degrees of Fahr., the cold produced by the expansion of the air, begins to condense the vapor and form cloud, and still as other air rises to that elevation it begins to condense likewise, and thus the base of the cloud remains at the same elevation, while the cloud goes on increasing in perpendicular height above. This is the kind of cloud which is formed almost every clear day in the summer when the dew point is not very low, but never forms when it is overcast. When the air is calm, if these clouds are observed carefully when they are forming, they will be seen to increase in perpendicular height while their bases remain at the same level. They rise in the form of pyramids or cones, with dense, well-defined outlines, as white as snow. If they do not meet with an upper current causing their tops to lean in the direction in which it is moving, they rise perpendicularly, and as they are broad enough even at their tops to lift up before them a considerable mass of air, it sometimes happens that in reaching strata of air highly charged with vapor it lifts them to a higher elevation, and causes a thin streak of cloud to be formed at some distance above the top of the columnar cloud. This streak so formed I have denominated a *cap*. It is generally a little curved convex above, and concave below, and as it moves slower upwards than the columnar cloud, the latter overtakes it and passes through it. Meanwhile the cap appears like a thin vapor spread over a mass of snow. Sometimes when a columnar cloud is very strong and rapid in its ascent, a second and even a third cap is formed, with similar appearances. When this happens, rain from the cloud is certain. First, however, the top of the cloud is seen to change its dense and well-defined appearance and become hazy. This is a sign that the cloud is about to rain, and in a few minutes, if the cloud is favorably situated, rain will be seen descending from its base. These appearances are all best seen when the base of the cloud is a few degrees above the horizon. The top of the cloud as it hazes is generally, in this climate, carried off by the upper current towards the N. E. and forms that feathery cloud which is so different in appearance from all other clouds. It is the highest of all the clouds except the tops of these columnar clouds, which generally rise through it.

In passing through it the columnar clouds generally form a very dense cap, and are sure to haze and rain soon after their passage. After they begin to rain they soon cease to rise; but other columns spring up contiguous to them, generally on the south west side of them, as far as I have observed, and as theory seems to indicate, and go through the same process of cap-forming, hazing and raining as the parent cloud.

These new columns, when they first make their appearance, I have denominated *sprouts*. This name is not inappropriate, for these sprouts are evidently generated, or at least assisted in their growth, by the parent column, in the following manner. As the parent column rises into the upper current of air, which generally comes from the south west or W. S. W. its top is made to lean towards the north east or E. N. E., but by its inertia it causes the current there to run a little slower, and so the column which may be about to form behind it towards the south west finds less difficulty

10

in rising, and preserves a more erect position, and thus can attain a greater elevation. Hence, the first attempts of columnar clouds to rain are generally failures, because their tops are generally shaved off or pressed over towards the north east, and thus dissipated without raining; each succeeding cloud in its wake finding a stiller air in its upward motion, attains a greater elevation. Finally, one reaches a height sufficient to produce rain, and then a new source of power is called into action, powerfully aiding the formation of sprouts. This is the descending rain cooling the air below the cloud, and causing it by its greater specific gravity, and also by the weight of the drops of rain, to move outwards in all directions from the centre of the rain.

Now as the air all round the parent cloud is running in at the base of the cloud, and below towards the cloud, this air is obliged to rise up over the stratum of cold heavy air, pressed outwards around the borders of the shower, and thus its upward motion is increased; and as the dew point is more likely to be higher on the south side of the cloud than on the north, sprouts will on that account be more likely to form on the south than on the north. To see the formation of sprouts to the greatest advantage then, the cloud should be to the north of the observer.

If these theoretical deductions are correct, and as far as observation extends it does not contradict them, it would follow, that the progress of rain may be from a northern direction, though the upper current may be constantly carrying the hazy cloud formed from the tops of all these columns towards the east. Further observations are wanting on this point.

I would recommend that gentlemen residing in mountainous districts, where the clouds sometimes form on the sides of the mountains, should ascertain the perpendicular height of these clouds at their base, and see whether they are one hundred yards high for every degree of Fahr. which the temperature of the air is above the dew point at the moment of their formation.

If gentlemen have no means of taking the dew point directly, the following method will be found equally correct in ascertaining the height of the base of these particular clouds, at any time of the day, for the height varies every hour. Swing a thermometer (Fahr.) rapidly in the air to avoid the effect of radiation, note its temperature, then cover its bulb with a wet rag and swing it as before until it sinks as low as evaporation can make it, then divide one hundred and three times the difference of these temperatures by the wet bulb temperature, the quotient will be the height of the base of the clouds in question, in hundred yards. For example, suppose the dry bulb is 56½°, and the wet one 51½°, then the base of the clouds will be one thousand yards high. This height is calculated on the supposition that air cools at 5° Fahr. in ascending to a height where the barometer would be one inch lower than at the surface of the earth, and 5° more for every additional inch. If this latter law is not strictly correct, the height of the base of the cloud in question will vary accordingly, and the law itself may be accurately investigated by this method, for the precise degree of refrigeration necessary to condense vapor at a particular dew point is known, after making an allowance for the expansion of the vapor itself and the fall of the dew point on this account. As the discovery of a method to ascertain by the thermometer the height of a particular kind of cloud, easily distinguishable from all others, is a matter highly curious in itself, independent of its connexion with the theory here advocated, it will no doubt receive that immediate attention which it deserves.

97. Since writing the above a kite was sent up into the base of a cloud, and its height ascertained by the sextant, and compared with the height calculated from the dew point, allowing one hundred yards for every degree the

dew point was below the temperature of the air; and the agreement of the two methods was within the limits of the errors of observation. In this case the base of the cloud was over twelve hundred yards high.

Moreover, the motions of the kite whenever a forming cloud came nearly over it, proved an upmoving column of air under it. I speak of cumulus clouds, in the form of sugar loaves, with flat bases.

SECTION THIRD.

LABORS OF THE JOINT COMMITTEE.

98. The interest which was awakened on the subject of storms about this time, induced the American Philosophical Society and the Franklin Institute to unite in forming a Joint Committee on the subject; and their principal labors are given below.

CIRCULAR.

Philadelphia, Sept. 1834.

Sir,—At a joint meeting of two committees appointed, one by the American Philosophical Society, and one by the Committee of Science and the Arts of the Franklin Institute of the State of Pennsylvania, to confer together on the best means of promoting the advancement of Meteorology, held at the hall of the Franklin Institute, on the evening of the 9th inst., it was resolved that a sub-committee be appointed to furnish a project for certain simple observations, which may tend to elucidate important points in Meteorology, and which may be at once entered upon, by observers in different parts of our country, and also to present a form of circular, to be forwarded to persons who may be considered competent to carry into effect the above objects.

In conformity with this resolution, and as a preliminary to the introduction of a more extended plan, which the joint committees are now maturing, the following circular has been prepared, and is forwarded to you by the committee.

The prime object of this circular is to obtain a complete knowledge of all the phenomena accompanying one or more storms of rain or hail, not only where the violence of the storm is felt, but at and beyond its borders, its beginning and its end.

For this purpose you are requested, immediately on receiving this circular, to commence a journal of the weather, noting the direction of the wind at the surface of the earth and in elevated strata, as indicated by the clouds, which may frequently be seen at different elevations, moving in different directions; the upper current of all being at Philadelphia, generally from some western point. Let the strength and direction of the wind, and the appearance of the heavens as to clear or cloudy, and the character of the clouds, according to your own mode of description, be noted at least three times a day, as near the following hours as convenient: 7 A. M., 2 P. M., and sunset. Let the heavens, however, be examined very often, so that any sudden change may not pass unobserved, especially in the direction of the wind; and when any occurs, let it be noted, with its time, under the general head of "Observations."

The plan which we recommend in observing slow-moving clouds, is to keep the head steady in one place, with the top of a chimney, or some distant fixed object, between the eye and any remarkable point of the cloud, until this point shall have moved so far from behind the object as to leave no doubt of its direction.

As to upper and lower strata, when one passes under the other, there is an optical deception to be guarded against when the upper one moves with the greatest angular velocity. The deception may generally be avoided by noticing which cloud is obscured by the other as they pass. Sometimes, also, an upper current of air may be detected when there is but one stratum of clouds, if these are of the columnar snowy-topped kind, which are frequently seen in a hot summer day: as these clouds are frequently formed between two currents, their tops will lean in the direction of the upper current, and, indeed, sometimes be blown off and dissipated, in a direction different from the air below.

We also particularly request, that if you hear of any storms occurring in your neighborhood, you will collect all the information concerning them in your power.

Particularly inquire the course of the wind at the commencement of the storm and at its termination; the width of the storm; its direction; its velocity; the direction of the wind at its sides; how the wind veers round — whether in different directions at its sides or not; whether, in case of hail, there are two veins or only one; where there is the greatest fall of rain, near the borders or near the centre of the storm — and whether this fall takes place near the beginning, middle or end of the storm; whether the clouds are seen moving with the wind or against it, and whether differently among themselves; and every thing else which you think may tend to an explanation of this most interesting phenomenon.

Let the time of beginning and end of all rains be particularly noted, any change in the strength and direction of the wind during their progress, and the quantity as near as possible. Mark the time of meteors, or shooting stars, and auroras, and if possible the stars through which they pass. These observations, if made by very many correspondents throughout the United States, will elucidate the main object which the committee has in view in the present circular, and it is hoped greatly assist in giving interest and value to the plan in contemplation. But as many observers may be willing to do more, we will remark that the observations on storms will be much enhanced in value, if accompanied by observations on the "dew point:" for it may be, that hurricanes never occur only when the dew point is high.

A very simple as well as accurate method of taking the "dew point" is, to use a thin tumbler of tin, kept very bright and clean on the outside — and in the summer cold water, and in the winter snow or ice, and if necessary salt, mingled with water — and when these are not at hand, a mixture of muriate of ammonia and nitrate of potash, in equal quantities, pounded very fine, put into the tumbler with water. By any of these means a temperature may soon be obtained below the "dew point." When dew settles on the tumbler it must be carefully wiped off, very dry, and the fluid within stirred with a thermometer — and this must be repeated until the fluid is gradually heated up by the air, so that the moisture ceases to settle: the highest temperature at which it will settle is the "dew point."

For observations of the dew point to be of any value, however, they must be made constantly, every day at least once a day.

Again, some may be unwilling to take the dew point, who would be glad to know it may be obtained, approximately, by the following indirect method:

Take two thermometers that agree, or allow for the difference — cover one of them with a wet white rag, and swing them simultaneously in the air, (for it will not do to let them be at rest, unless the wind is blowing fresh); when it is discovered that they cease to change by swinging, take 103 times their difference, and divide it by the wet bulb temperature, and subtract the quotient from the temperature of the naked bulb — the remainder will be the dew point. This formula is founded on experiments from 20° Fahr. to 80°, and does not differ, at either extreme, from the most careful experiments. We cannot refrain from saying, we are sure that every lover of the science will be richly rewarded for all the pains he may bestow on the dew point, even independent of the results which will undoubtedly be derived from a comparison of these simultaneous observations.

In conclusion, the committee request that, should your occupations prevent you from attending to the subject yourself, you will find in your vicinity a competent observer to take your place.

Please to forward your observations monthly, to the Joint Committee of the American Philosophical Society and Franklin Institute, care of William Hamilton, Actuary of Franklin Institute, Philadelphia, by mail, when a private conveyance is not at hand.

James P. Espy, *Chairman Joint Committee.*
Gouverneur Emerson, M. D.
C. N. Bancker,
Alexander D. Bache,
Com. of Amer. Philos. Soc.
James P. Espy,
Alex. D. Bache,
H. D. Rogers,
S. C. Walker,
P. B. Goddard, M. D.
Com. of Franklin Institute.

Day.	Hour.	Temperature of Air	Temperature of Wet Bulb.	Dew point.	Course of Wind.	Lower strata of Clouds.	Middle strata of Clouds.	Upper strata of Clouds.	Strength of Wind.	Weather.	Beginning of Rain.	End of Rain.	Barometer.	OBSERVATIONS.

First Report of the Joint Committee of the American Philosophical Society, and Franklin Institute, on Meteorology.

99. The Joint Committee of the American Philosophical Society, and the Franklin Institute of the State of Pennsylvania, return thanks for valuable meteorological journals, received from the following gentlemen:

Mr. R. H. Gardiner, Gardiner, Maine.
Mr. Jacob Mull, U. S. Navy, Portsmouth, N. Hampshire.
Mr. James Porter Hart, Farmington, Mass.
Professor Caswell, Providence, R. I.
Mr. A. W. Smith, Middletown, Conn.
Mr. Edward Gibbons, Lockport, N. Y.
Mr. C. Gill, Flushing, Long Island.
Dr. R. H. Rose, Silver Lake, Pa.
Dr. Henry Gibbons, Wilmington, Del.
Dr. G. S Sproston, U. S. Navy, Baltimore, Md.
Dr. J. M. Foltz, U. S. Navy, Washington city, D. C.
Professor James Hamilton, Nashville, Tenn.
Dr. John Locke, Cincinnati, Ohio.
Mr. J. Panglos, Urbana, Ohio.

Only four months have elapsed since the reception of the earliest of these journals, and already some valuable facts have been deduced from a comparison of the simultaneous observations which they contain.

A detailed report of all general conclusions, with the data on which they are founded, will be given hereafter; but as this will require a considerable length of time, and a much more extensive collation of journals than the committee have yet in their possession, they will mention, with a view to increase the zeal of their correspondents, one or two facts, which, from further observations, will probably lead to important general laws.

In all the great fluctuations of the barometer which occurred in January and February, 1835, at Nashville, Tenn., they were one day sooner than at Philadelphia; and on the 22d of March, the barometer was lowest at Philadelphia at three o'clock, P. M.; whereas, at Providence, R. I., it continued to fall till nine o'clock, P. M., as very particularly noted by professor Caswell. The exact moment of greatest depression at Portsmouth is not given by Mr. Mull, but it was lower there at seven o'clock, P. M., on the 23d, than on the 22d at sunset; at which time it had already risen more than half an inch at Philadelphia.

Do these barometric fluctuations of great magnitude travel north eastwardly? [1]

Again, on the 22d of March, at the moment when the barometer was lowest at Philadelphia, the wind at York, Pa., at Flushing, N. Y., at Middletown, Conn., at Providence, R. I., and at Portsmouth, N. H., was blowing towards Philadelphia violently, especially at York and Portsmouth, while at Philadelphia it was a perfect calm. There was also, on that day, a very violent rain at York, and in Berks county, Pa., and at Baltimore, and also a considerable rain at Flushing, Middletown, and Providence, at the same time, when there was a calm in Philadelphia, and no rain; and as this state of things continued for many hours, it seems probable that the air, which moved with great rapidity towards Philadelphia, in opposite directions, must have ascended over Philadelphia, and passed off above even with greater rapidity than it approached below, or otherwise the barometer must have risen, in a very short time, to a great height, by the conflicting impulse of these two opposite currents; but the barometer stood all this time more than three quarters of an inch lower than usual.

[1] Many facts have come to my knowledge since, that lead me to believe that barometric fluctuations, of great magnitude and extent, travel towards a point a little south of east. — AUTHOR.

The committee desire these remarks to be viewed as they are intended, to be confirmed or rejected as future observations, and a more extensive induction, shall warrant. They merely propose the queries —

Are rains caused by an upward motion of the air, commencing where the dew point is highest, or where the barometer is lowest?

Do storms in the temperate zones generally travel from some westerly point? And are those storms which so travel preceded by an easterly wind, and also followed by a westerly, unless another storm is soon to come on in the same direction? In the torrid zone, do the storms on the north side of the line travel towards the north west, and on the south side of the line towards the south west?

On the 29th of January, from eight o'clock, A. M., till four o'clock, P. M., there fell at Nashville, Tenn., 1.47 inches of rain. This storm travelled east, and it began to rain at Cincinnati at half past twelve o'clock, and at Philadelphia at four o'clock next morning, the 30th; it rained hard all day, terminating at seven o'clock, P. M. During this whole day, the wind at Nashville and Cincinnati blew towards Philadelphia, and at Flushing, Middletown, Providence, and Portsmouth, directly towards Philadelphia also. This storm lasted eight hours at Nashville, fifteen hours at Philadelphia, twenty-four hours at Flushing, and twenty-seven hours at Portsmouth. The wind set in at all these places some hours before the rain from the north east, and at the termination of the rain, changed to the south west; and before it ceased raining at Portsmouth, the wind had changed round by south to west at Flushing and Philadelphia, and to the south west at Middletown.

Even one well authenticated case of this kind goes far to establish the fact that the wind below blows towards the centre of a *great* rain. From the time of the middle of the storm at Nashville, until the middle of the storm at Philadelphia, was twenty-three and a half hours, and this corresponds well with the fluctuations of the barometer mentioned before.

It may be mentioned, also, that, reckoning from middle to middle of the storm, it was thirty and a half hours from Nashville to Middletown, and thirty-two and a half from Nashville to Portsmouth. These all agree in giving a velocity to this storm of about twenty-six miles an hour. *Is this the velocity of the upper current of air at Philadelphia, which comes generally from a point south of west? Is it this upper current which gives direction to the storms in this latitude?*

Many instances have been observed upon a momentary breaking of the lower clouds, in the very middle of these north east storms, when the clouds above were coming from south west.

This storm had a north east and south west diameter, at Nashville, of about two hundred miles, gradually increasing in size until, at Portsmouth, it was eight hundred miles. Its north west and south east diameter is unknown.[1]

What are these two diameters of storms generally?

Our correspondents will perceive that something on this subject is likely to be discovered by a persevering course of simultaneous observations over our wide extended continent. The Joint Committee which now addresses you will spare no means to elicit from your observations, decisive answers to the queries proposed above, and, if possible, to establish such general laws as will entitle meteorology to the name of science.

To this end, it is essential that the original observations, and not the mean of several, should be communicated, and that the number and extent of our correspondents should be increased; we therefore request each one of our correspondents to procure at least two more. It would be very

[1] Much more on this subject is known now, as will be seen hereafter.

desirable to have different correspondents at places along our northern frontier, and others on our sea-board, from Cape May to Cuba. Also, to have some correspondents in the *far west;* we have none at present further than Nashville.

The committee earnestly request that the present opportunity of discovery may not be lost; that the undertaking may not languish for want of zeal; their correspondents may be assured, even when the committee is silent, that they are constantly at their posts, waiting for the communications with that intense interest which always accompanies sanguine hopes of successful investigation.

Second Report of the Joint Committee on Meteorology, of the American Philosophical Society and Franklin Institute of Pennsylvania, for the Promotion of the Mechanic Arts.

100. In commencing this report we have still to regret that the extent of our correspondence north west and south east is not great enough to enable us to ascertain the boundaries of our great storms in those directions; and of course we cannot determine the direction of the winds in those boundaries — a knowledge which we believe to be of the highest importance to the science of meteorology. The committee do not yet despair, however, of extending this correspondence so far as to attain so desirable an end, and with the hope of aiding this extension, proceed to give an account of a few of the most remarkable storms which have occurred since their first report.

These we are sure will be found to be highly interesting, even with the imperfect knowledge which our limited correspondence enables us to give of them. It will be seen that the character of some of them varies from our great north east storms which come from the south west. They seem to have travelled southwardly or south eastwardly, as will be seen by the storms of the 14th and 15th of May, of the 20th of May and 19th of June, 1835.

It is much to be hoped that gentlemen throughout the country who may see this report, will communicate to us any fact connected with the storms here detailed, which may either be favorable or adverse to the generalization upon which we have ventured.

It would be particularly desirable to know the boundaries of the great rain which took place on the 19th of June to the north east. For this purpose, if gentlemen living in Vermont and New Hampshire, and the north of New York, would consult their meteorological journals, and let us know whether it rained there at that time or not, and which way the wind blew, they would confer a great favor on the committee. From the nature of the remarks below, it will be understood what kind of information is wanted. We hope every gentleman to whom this is sent will be induced to furnish a faithful correspondent, who will at least carefully observe all storms, their beginning and ending, and the course and changes of the wind, during their progress. The labor, though great, of collating numerous journals, and deducing from them general conclusions, will be cheerfully continued by the committee. These journals are carefully preserved in the archives of the Franklin Institute, and will be accessible to any meteorologist who may wish to consult them.

101. We now proceed to detail the phenomena attending the most remarkable rains and storms which took place between the date of our first report and the eleventh of November, 1835; and to enable the reader te comprehend the report with greater ease, we recommend him to bear in mind this remarkable generalization — *In all the seven storms examined, the wind blew towards the point where it was raining.* To this rule there is not one exception; for though

the very first storm mentioned, that of the 26th of April, terminated at Philadelphia, and passed on to the north east, with the wind still from the north east, it appears plainly that a much greater storm was raging at that very time at no great distance to the south west, in the very direction towards which the wind was blowing.

The storm of the 20th of May was evidently too local in its character to form an exception. As it is known, however, that many of our summer storms set in with the wind near the surface of the ground, blowing from the centre of the storm, it becomes a question of high importance to investigate the cause of this difference.

102. *Storm of the 26th and 27th of April*, 1835. — On the night of the 25th and morning of the 26th of April, *at Philadelphia*, there was a great rain, with the wind at north east. At the end of the rain the wind continued from the north east with abated violence, being almost calm on the morning of the 27th, with the lower clouds from the W. N. W. and the upper clouds from the west. At three P. M. the wind was from the east, pretty fresh. At six P. M. a very great rain commenced, which continued through the night, the wind changing round by the north, and at ten the next morning it still rained very hard, with the wind from the north west, and violent. The rain began to abate at seven, the wind still being violent from the W. N. W. and at eight the rain ceased, with the wind W. N. W., its violence having a little abated. The barometer was now rising rapidly.

At *Cape May*, on the night of the 27th, the wind was violent from south.

At *Baltimore*,[1] the rain was very great on the night of the 25th, and continued the most of the day of the 26th. The wind was north east all day on the 27th. The rain

[1] Our correspondent is Dr. G. Sproston, U. S. Navy.

began at three, P. M., became heavy at four, and continued so through the night. On the morning of the 28th, the wind was north west, and scud and heavy cumuli were rolling off to the south east. The wind was west in the afternoon.

At *Flushing*, Long Island, New York,[1] after the rain of April 25th and 26th, the wind continued north east, till half past two o'clock, P. M., of the 27th, when it was south west. At six it was south, and at seven P. M. it changed suddenly to south east. The rain commenced at nine, P. M., and continued till half past twelve, P. M., of the 28th. The wind was very high. In the morning, it was north east, and at noon north west, continuing so all day.

At *Middletown*,[2] Connecticut, after the rain of the 25th and 26th, the wind was variable till some time on the night of the 27th, when the rain commenced, and continued violent. The wind was easterly till eleven, A. M., when it changed to south east, at noon to south, and at two P. M. to west, the rain continuing with unabated violence all the forenoon. From five, P. M., of the 26th till noon of the 27th, the barometer fell more than an inch. The wind westerly in the afternoon.

At *Brown University*,[3] Providence, Rhode Island. After the rain of the 25th and 26th, the wind hauled round by the north to the north west, and cleared on the evening of the 26th. On the 27th, the wind came round to the east in the afternoon, and the evening was cloudy. On the 28th, from three to four, A. M., there was a heavy blow from the east, with copious rain; at ten, A. M., the rain ceased, the clouds beginning to be broken, and the wind violent, hauling southerly. At one, P M., the wind was south west, very heavy; at four, P. M., the wind was westerly, its violence

[1] Our correspondent at Flushing is Mr. C. Gill.

[2] Our correspondent is Mr. A. W. Smith.

[3] Our correspondent is Professor Caswell.

had abated, and the clouds were broken. The barometer began to rise. The weather cleared from nine to ten, P. M., the wind having abated; on the next day the wind was westerly.

103. *Storm of the 4th and 5th of April,* 1835.—*Brown University.* On the 3d of April, 1835, there was a great rain in the night, commencing between eight and nine.

On the 4th, at sunrise, the wind was north east, but during the morning it hauled to the north and north west; towards night swung back to the north east, and blew heavily during the night. There was a mist, but no rain.

On the 5th, at sunrise, the wind was heavy from the north east; there was rain occasionally during the day. From seven to eight o'clock, P. M., the wind came round to the south west. The clouds had broken away at nine, and the sky was clear at ten.

6th, light shower at nine, P. M., wind south west.

Baltimore, Maryland. On the 3d, the wind was east, south east and east. There was a light sprinkling of rain from two to four, P. M. The sky was overcast in the evening.

On the 4th, the wind was east in the morning, south east in the afternoon, with a sprinkling of rain at fifty minutes past ten, A. M., to twelve. The rain recommenced at nine, P. M., with lightning, and continued with high wind through the night, turning to sleety snow at twenty-five minutes past nine, A. M., of the 5th, and terminating at fifty minutes past ten, A. M., with the wind east. At twelve the wind changed round to the west, with a heavy reflux of cumuli from the east. At sunset the wind was south west, with some rain; starlight at ten, P. M.

Philadelphia. On the 3d and 4th, the wind and lower clouds were from the north east, the upper clouds from the south west, and middle clouds from south west, with very hard rain, commencing some time in the night of the 4th, with thunder and hail; continuing on the 5th very hard, with wind E. N. E., violent till half past ten, A. M. The wind changing to east at eleven, blew less violently, and was S. S. E., at one P. M. nearly calm; the lower clouds south. The wind was south at half past three, P. M., strong on the 6th, the wind moderating a little. The rain ceased at noon; very little in the afternoon.

At *Flushing*, Long Island, N. Y. On the 4th, the wind rose at half past ten, P. M., north east, having been gentle in that direction for two days. It was very high the next morning in the same direction, at a quarter past seven; at quarter past twelve was very high from the east; at half past three brisk from the south east, and at six high from the south west. Rain commenced with thunder, at half past eleven, A. M., and with some intermission ended at two, P. M.

At *Baltimore*. On the 4th of May, at half past three, P. M., a nimbus rose from the west, against a strong south east wind; it burst at four, with thunder and lightning, and rained nine tenths of an inch.

104. *Storm of May 15th*, 1835.—*Norfolk*,[1] Virginia. On the morning of the 15th, there was a great rain, ending at twelve o'clock. At *Philadelphia*, all that morning there was a strong wind and lower clouds from north, and upper clouds from S. S. W., continuing till four, P. M., when the clouds disappeared. During the same morning, at *Brown University*, the wind was north east; with misty rain till twelve.

At *Flushing*, the same morning, the wind was high from the north east, the lower clouds from the north east, the middle from the north, and the upper from the west, and at *Cincinnati*,[1] Ohio, south west.

This rain seemed to have travelled south, for it ceased to rain at Philadelphia on the 14th, at half past twelve; with

[1] From the newspapers.

the wind changing from north east to north, it continued to rain hard at Baltimore, at three P. M., and only ceased at four. Or as it rained a little on the 15th, at Brown University, till twelve, did it spread outwards in all directions from some centre?

At Portsmouth, sharp lightning south east, at half past eight, P. M.

Storm of the 20th of May. — This last appears to be the character of a rain which occurred on the 20th of May, at *Silver Lake*,[1] Pennsylvania. On this day, at one, P. M., a violent thunder storm commenced, with hail from the west, the day having been clear till that time.

At *Farmington*, Connecticut,[2] a violent storm commenced at four, P. M., and lasted till nine.

At *Flushing*, a violent thunder storm began at five, and lasted half an hour, preceded by a squall of wind from the west, the wind having been all day west.

At Brown's University, a light shower, with thunder and lightning, from six to eight, P. M., wind south westerly all day.

At *Philadelphia*, about seven, P. M., a strong wind commenced suddenly from the north west, it having been pretty strong from the S. S. W. all day; at the same time when the wind began to blow from the north west, the lower clouds were coming from the south west, and the middle clouds from the north west; at eight o'clock it began to rain, barometer rising .05 of an inch in an hour. There was some thunder, but not much rain till some time in the night.

At *Baltimore*, it was clear on the 20th, at ten, P. M., and did not begin to rain till late in the night, and it continued showering the next day till a quarter past nine, P. M.

[1] Our correspondent is Dr. R. H. Rose.

[2] Our correspondent is Mr. James Porter Hart.

105. *Storm of July 15th*, 1835. — At twelve o'clock a violent rain, with hail, commenced at *Baltimore*, with the wind north east, continuing till seven, P. M. The course of the wind in the afternoon not given, but on the next day it was west; on the same afternoon and evening there fell tremendous floods at *Woodbury*, New Jersey. At five, P. M., when it was raining hard in New Jersey, the wind changed to north at *Philadelphia*, with very dense black clouds coming rapidly from the south, and at six o'clock a most violent rain commenced, lasting till about eleven, P. M., with the wind from the north. During all this time there was a most violent gale at *New York*, from the north east; the rain commencing there at nine, P. M., while at *Washington City*, the wind continued all day and the next from the south west, with rain on the 15th, at what hour not mentioned. At *Lancaster*, Pennsylvania, the wind was north, with rain, which is not stated to have been remarkable. From the phenomena here recorded, it appears that the wind below at New York, Philadelphia and Washington City, was blowing towards a point in New Jersey, for several hours, at the same time when it was raining there most violently. The same was the case at Philadelphia, at least the clouds were coming thick and dark above, from the same point, while the wind below was going to that point.

106. *Storm of November 11th*, 1835. The particulars of this remarkable storm will be given hereafter; at present we will only say that at *Oswego*, in the south east corner of Lake Ontario; at the *Ducks*, in the north east corner; at *Buffalo*, and various other parts in the south western part of that Lake, the wind, when it was most violent, blew for several hours towards a point in the Lake, near the eastern end, on the morning of the 11th of November, and it changed round by the south, on south side of the Lake, and by north, on north side, to westward.

The north west corner of this Lake has not yet been heard from. Perhaps some gentleman in *Toronto*, or some place on the north side of the Lake, will have the goodness, on seeing this report, to send us the desired information.[1]

107. *Tornado of June 19th*, 1835. On the 19th of June, it rained all day at *Oxford* and *New York*, with the wind south in the morning, south west in the afternoon.

North of *Albany* there was a very great rain, beginning about eleven, A. M., as we have been informed by Mr. Guynne, who was travelling there that day, and at *Albany* it rained 2.45 inches in the afternoon and evening; wind south in the morning, north in the afternoon.

Brown University. June 19th was clear in the morning, with the wind light from the south west. The wind freshened towards night; the air very damp, with heavy fog clouds from southerly. Began to rain from eight to nine, P. M., with wind very brisk from south west. Rain 0.4 inches.

Middletown, Connecticut. June 19th, wind south all day; very strong in the evening; rain at noon, and a thunder shower commenced at six, P. M. The barometer was lowest on the morning of the 20th; a gale all the next day from the north west.

Portsmouth, N. H. June 19th, wind south at seven, A. M., south east at two, P. M., and E. S. E. at sunset. On the 20th, gale from half past eight, A. M., till half past seven, P. M., west by north, with rain from seven, P. M., till three, A. M. of the 21st; at seven, A. M., of the 20th, lower clouds west by south, upper W. N. W.; barometer lowest on the morning of the 20th.

At *Mr. Bloomfield's*, four miles east from Piscataway, New Jersey. June 19th, about ten, P. M., the wind began

[1] I have not been able to learn any thing more of this storm, and a diagram is merely given at the end of this report, showing the course of the wind at three places where it was very violent, with the original documents.

AUTHOR.

to blow hard from the south west, and increased in violence till about two, A. M., of the 20th, when it began to abate, and about dawn was nearly calm; during all this time very black clouds, accompanied with terrific lightning, without thunder, almost incessant, were coming exactly against the lower wind from the north east, or perhaps a little north of that point, with clouds occasionally meeting them, moving with the wind, and the interval between the very black clouds was so bright and silvery, that the stars could hardly be distinguished. About sunrise the north east wind began to blow, and by eight, A. M., had increased to a gale, perfectly clear; continuing violent till about twelve, M., when it began to abate, and at two, P. M., it had died away. Next day it was strong from the south west.

19th. On this same day, about five, P. M., a violent land spout took place at New Brunswick and its vicinity. It appeared in form of an inverted cone of smoke, reaching the ground with its apex, and its base among the clouds; it lasted only a few moments in a place, and progressed easterly, a little north, with a slow motion, not more than twenty or thirty miles an hour; it was about two or three hundred yards wide, and within that breadth left neither trees nor houses standing; all the trees were thrown inwards, and generally forwards; many of the houses had their walls prostrated outwards, and the shingles were thrown down in great numbers in Staten Island, along with a shower of hail and rain, from fifteen to twenty-five miles north east from where they were taken up. During the fall of the hail, on the north side of the vein, the wind was strong from the south, and on the south side of the vein, the wind chopped suddenly round to the north, the wind having been south west before. At the distance of a few hundred yards from the spout at its passage, the wind was not remarkably strong.

In conclusion, we recommend to our correspondents to observe and note every phenomenon which may tend to establish or refute the generalization to which we turned their attention at the commencement of this report. It is a remarkable fact, and altogether consistent with the generalization here spoken of, that all our great storms which set in from some eastern point, terminate with the wind from some western point; and our correspondents will recollect that all the phenomena detailed in our first report lead to the same conclusion. Among the storms there detailed, not the least remarkable was that on the 22d of March, 1835, in which there was a perfect calm at Philadelphia for several hours, with an extremely low barometer, the sky was very cloudy, without rain, while at the same time there was a most violent rain all round Philadelphia, with very strong wind towards Philadelphia.

Was the air at this moment rising over Philadelphia so rapidly as to carry up the drops of rain and throw them off at the sides of the ascending column? Both the rapid afflux of air towards Philadelphia, at that time, and the extreme depression of the barometer there, lead strongly to an affirmative answer. How extremely interesting would it be if our correspondence were wide enough to trace these storms to their commencement, and follow them to their termination.

And if our present attempt should fail to stimulate men of science to engage in the undertaking of investigating the dynamical laws to which the movements of the atmosphere are subject, and this can only be done by simultaneous observations over a wide extent of territory, then this committee, *unless aided by Government*, will have to leave the work unfinished, and reluctantly close their labors, with perhaps one more report.

Great Ontario Storm of 11th November, 1835.

Extract of a letter dated Henderson, P. O., Jefferson Co., Nov. 17.

108. The blow last week produced terrible effects on Lake Ontario. It looked like a boiling pot, as white as a sheet. The shore is strewed with broken pieces of vessels; hands and passengers of more than one vessel are known to have been lost. Several men from Henderson have been drowned. There was none escaped to tell the news.

From the Kingston (Upper Canada) Chronicle.

On Tuesday morning, the 10th, the steamboat Cobourg left Toronto on her trip downward; the weather being then quite moderate, she reached Cobourg on the evening of the same day; the weather still continuing the same, she left Cobourg at ten o'clock, but had hardly gone ten miles, when a heavy gale from the north east began to blow, and continued to increase till three o'clock the next morning. The wind then suddenly chopped round and blew a perfect hurricane from the north west. At four o'clock saw a schooner on her beam ends, about half a mile from the Ducks, floating, it was supposed, in fifteen fathoms water. Two men were seen clinging to the wreck; one of the sufferers had a stick in his hand, at the top of which was attached a handkerchief, which he waved as a signal of distress. The state of the weather, however, was such that the Cobourg could render no assistance. The sea at this time was washing over the decks of the Cobourg in every direction, and breaking into the cabin through the deck windows. Capt. Paynter was therefore reluctantly obliged to leave the unfortunates to their fate. The schooner, from the appearance of the hull, was supposed to be the Ontario, belonging to Oswego. A short time afterward saw another schooner about two miles from the Ducks, also afloat on her beam ends, but no appearance of any living creature was seen about her; it was supposed all had perished. The Cobourg for five hours suffered the extremity of the gale, during that time her bows were almost constantly buried in the mountainous sea which foamed around her, and she shipped at intervals some heavy seas. On arriving opposite to Kingston, where she had to land three cabin and fifteen deck passengers, such was the violence of the storm that she could not possibly approach the port; she therefore had to carry them down with her to Prescott, and land them at Kingston on her return.

Extract of a letter from Zeno Allen to James P. Espy, dated Sackett's Harbor, Jan. 8, 1836.

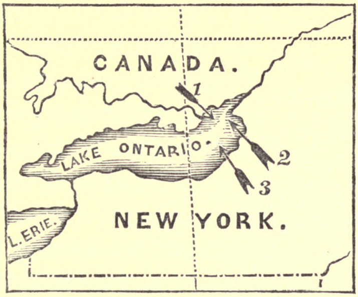
Between twelve and two o'clock on the morning of the 11th November, the wind sheered from south to S. S. E., and remained there till about six o'clock in the morning, when it veered to S. S. W., blew hard and commenced raining. The wind continued from this point or about south west till 9 P. M., blowing a perfect gale, with snow and hail.

Extract of a letter from C. J. Brinkle to James P. Espy, dated Oswego, Nov. 27, 1835.

The storm commenced here about nine o'clock, P. M. of 10th inst., from the south east, and continued so till about 9 A. M. of the 11th, when it chopped round to the south west. Capt. Homans, of steamboat Oswego, thought it prudent to remain in port, the storm was so severe, for it became almost a hurricane.

If the reader will examine these documents carefully with a large map before him, he will discover that the wind at Oswego blew as if there might have been a whirl from left to right, and at Sackett's harbor as if from right to left. This storm, therefore, was probably oblong, with its longest diameter N. N. E. to S. S. W.

CHART showing the direction of the wind near the centre of the storm, from 3 to 6 o'clock, A. M., of the 11th November, 1835.



No. 1, The Ducks. No. 2, Sackett's Harbor. No. 3, Oswego.

CIRCULAR.

PHILADELPHIA, June 11th, 1836.

109. The Joint Committee "on Meteorology," appointed by the American Philosophical Society and the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, being very desirous of ascertaining the boundaries of the great storms which traverse the United States, and the direction of the wind in those boundaries, take the liberty of requesting you to inform them when the rain began and ended at your place; in what direction the wind blew during the rain, and, if possible, how and when it changed; whether it was violent or gentle, and whether there was much or little rain. These questions relate particularly to the great rain at the end of May and beginning of June. But if the same questions should be answered as to all the storms which may occur within the next twelve months, by all to whom this circular is sent, the result cannot but be highly interesting.

This storm, which has been so general on our seaboard, began at Philadelphia on the 26th of May, at half past seven, P. M. and ended on the sixth of June, at three, P. M.

It rained moderately hard on the nights of the 26th and 29th of May, and first of June, and on the afternoon and night of the third, and all day on the sixth, till three o'clock. There was but little rain on the other days. The wind was steady all this time and two days before, from E. N. E. and east by north quite strong on the evening of the 26th and morning of the 27th; all day of the 30th and 31st, and first of June, and the morning of the second, and all day the 6th, till six or seven, P. M., when it died away and turned round to south east. The wind, however, got back to north east again on the seventh, with a shower at four, P. M., and did not clear up till the 8th, and even then deep columnar or pyramidal clouds were seen forming to the south east and south, with rain descending from their bases.

By order of Joint Committee, &c.

THIRD CIRCULAR OF THE JOINT COMMITTEE ON METEOROLOGY.

PHILADELPHIA, June 27, 1836.

110. The Joint Committee "on Meteorology," appointed by the American Philosophical Society, and the Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, being very desirous to ascertain the boundaries of the great storms of rain which traverse the continent of North America, as also the direction of their motion and their velocity, with the direction and force of the wind in those boundaries, take the liberty of requesting you to give them the particulars of the storm which has just terminated, being the *second* long easterly storm which has occurred here this summer. When the rain commenced at your place; *in what direction the wind blew during the rain;* and, if possible, how, and when it changed; whether it was violent or gentle, and whether it and the clouds moved in the same direction or not; in what direction the upper clouds moved as well as

the lower, and whether there was much or little rain. We beg you not to be deterred from answering this communication, even if you should be enabled to answer only one of the questions, particularly the *direction* of the wind. As many to whom we shall send this " circular " may not be able to answer these questions as fully as might be wished, we particularly request that an answer may be sent to similar questions as to the great equinoctial storm which takes place generally near the 20th of September ; or, to ensure success, please to extend your observations to the middle of October. If all to whom this circular is sent shall do as requested, we are sure the result will be highly important to Meteorology.

The north east storm, which is the immediate object of this circular, commenced at Philadelphia on the 20th of June. It was very warm and nearly calm early in the morning, wind south west, middle clouds south east, and upper clouds west, having been preceded by a very heavy shower from the W. S. W. on the afternoon before, and also a hard rain with much thunder in the evening from the south. During the morning of the 20th the wind changed round from east to E. N. E. and blew hard; it commenced raining at five o'clock, with a strong wind from E. N. E. and continued quite hard all night. The wind moderated next day, but continued about E. N. E., moderate, till about six, P. M., of the 27th, when it changed round to N. N. E. and cleared suddenly. The rain ceased at six, A. M., of the same day, having rained hard for sometime in the night of the 25th, till the morning of the 27th ; the wind was very gentle on the 26th, when it rained hard all the afternoon.

There was but little rain from the morning of the 21st till the night of the 25th, except on the 23d from three till six, P. M.

On the 22d, 23d, 24th, 25th and 27th, the lower clouds broke away two or three times, and through the breaks the upper clouds were seen coming slowly from the south west, not very thick. It was calm on the afternoon of the 27th after it cleared up. The wind, however, changed to north west by the north. By order of the Joint Committee, &c.

Third Report of the Joint Committee on Meteorology of the American Philosophical Society, and the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts.

111. In our two previous reports we gave an account of nine storms, in all of which the wind blew towards the storm in its borders.

Two very remarkable storms have occurred since; one commenced on the 23d of May, and continued to the 7th of June; the other occurred on the night of the 19th and the day of the 20th of June. Immediately after the termination of these storms, the committee addressed circulars to a great many individuals throughout the United States, requesting an account of them, particularly with regard to the rain, and the strength and direction of the wind. Our inquiries were not in vain. We received very satisfactory replies from many in the region of the storms, and beyond their boundaries. It would be highly desirable to give the documents to the public, entire, but our present means will not permit.

It is hoped that when government shall become acquainted with the important discoveries already made, and the absolute necessity of combined and simultaneous exertions, beyond the reach of individuals, their liberality will be cheerfully extended to the promotion of this science, in our widely extended country.

In the mean time, we must content ourselves by giving a few general results, as we did in our previous reports.

In the first place, we remark a very striking difference between the first of the two storms mentioned above, and all the winter storms investigated before in our reports; all the winter storms, as well as the tornadoes or land spouts in the summer, seem to travel from a point south of west, while this long-continued storm was nearly stationary, inclining, indeed, a little towards the south west, as it continued to rain in North Carolina and South Carolina, some days after it ceased at Philadelphia. The Alleghany Mountains seem to have been near the centre of the rain, extending from the western parts of New York to South Carolina. The rain was copious as far west as Cincinnati and Lexington, Ky., and as far east as the shores of the Atlantic, hardly reaching Illinois, and extending but little way into the Atlantic, and not prevailing much as far north east as Massachusetts.

Now, in Massachusetts, Connecticut, and New York, the wind was constantly blowing from the north east during the whole period of the storm. In Charleston, S. C., constantly from the south and south east. In the interior parts of the storm, the wind was variable; the prevailing winds, however, in the northern parts of Ohio being from the north, in Illinois from the west, and in Alabama there seems to have been nothing remarkable; no north east storm occurred, but the direction of the wind is not given.

It also appears by the log books of several masters of vessels who left the Gulf of Mexico, about the beginning of this storm, and arrived at Philadelphia about the end of it, that they had the wind constantly from the south west and south and south east fresh the whole way, gradually passing the south and nearing the east as they approached to Philadelphia.

Thus it appears that on the north east and east, south and south west, the wind was constant, for at least fourteen days towards a great rain, and that on the other part of the circle, even within the boundaries of the rain, the wind, though variable, prevailed in a direction towards the centre of the storm.

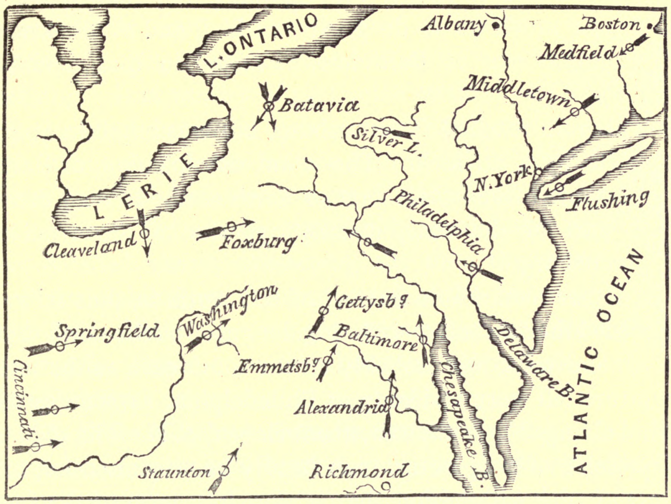
In this storm then, as in the nine investigated before, the wind blew towards the centre, and consequently upwards in the middle — and outwards above — at least in Massachusetts. Mr. Daniel C. Sanders, of Medfield, seventeen miles south west of Boston, says: "often there were three strata of clouds, the upper one very high, moving from the west, nearly opposite to the lower stratum. The middle one was very changeable in its direction."

And also at Bennington, Vermont, Mr. Jonathan Hunt says; "In almost all violent storms from the east, there is an upper current from the west."

There is therefore the strongest reason to believe that rain is caused by the cooling produced by the rarefaction of the air in its upward motion in the centre of the storm.

112. The storm which commenced on the night of the 19th June, is not less remarkable than the one just described. It seems also to have travelled south or south west, for on the night of the 19th, and the next day, the rain was greatest at Silver Lake, in the northern part of Pennsylvania, and on the night of the 20th, and the next day, it was greatest at Baltimore, and it did not reach Hawsburg, Rappahannock county, Va., till the 21st, when it rained very heavily, the wind having veered round to the north east. At Staunton, Va., it was clear all day the 21st and 22d, till evening, and the north east storm did not set in till the 24th.

In the wood cut we have given the direction of the wind by means of arrows at all the places from which we have any accounts. On the 20th of June, there fell nearly three inches of rain, including that of the preceding night, at Silver Lake. Much more rain fell here than at any of the surrounding places of observation. There was but little at Foxburg, Gettysburg, and Harrisburg, and it did not commence at Baltimore till half past seven o'clock, P. M., nor at Emmettsburg till four o'clock, P. M., nor at Philadelphia till ten minutes past five o'clock, P. M.



By casting the eye on the wood cut, it will be seen at a glance that the wind blew on all sides towards the point of greatest rain.

But what is not a little remarkable, the wind was much more violent all round the borders of the storm, than near the centre.[1] At Harrisburg and Gettysburg it was gentle, and at Emmettsburg it was tempestuous. It is true it did not begin to be tempestuous till four o'clock, P. M., and at Philadelphia it did not begin to blow very hard at the surface of the earth, till about eleven, A. M. At seven, A. M., it was very calm, though the low clouds were flying with great velocity from the south east, exactly towards the region of the great rain.

[1] It has since been ascertained that during the day of the 20th, the wind at Silver Lake was so variable that it was difficult to know from what point it prevailed most.

It is also worthy of particular remark, that the wind at Emmettsburg was north west on the 21st, blowing towards a region where it rained that morning and the preceding night, so much as to do great mischief, and even as near to Emmettsburg as Baltimore, it rained in that time 1.7 inches.

This rain reached Emmettsburg, but was small in quantity, viz. $\frac{26}{100}$ of an inch. The wind on this day, at Baltimore, varied from south east to north east. It was, therefore, part of the time, exactly opposite to the wind at Emmettsburg.

Another remarkable feature of this storm is, that it was preceded the day before with thunder gusts, on the north east, north and west, and probably on the south east, as the temperature fell very suddenly at Philadelphia, as soon as the wind changed to south east, about eleven, A. M. The sudden depression of temperature can hardly be accounted for, except on the supposition that a thunder storm took place during the preceding night, south east of Philadelphia. The temperature had not changed at Harrisburg, at one, P. M., nor at Emmettsburg at half past two, where the wind continued all day from the south west.

Besides these two storms, we may mention one which took place on the night of the 10th March, 1836. The centre of greatest rain appears to have been at Providence, R. I., where it began at six, P. M., and rained most violently till twelve at night. The papers of the day give accounts of great damage done by the floods near Providence; and they state that the wind sprang up and blew violently from the south east, at Bristol, R. I., some time in the evening, and raged from that quarter till five next morning, and then changed round to south west, and continued strong.

At Flushing, Long Island, the wind was almost calm at three quarters past five, P. M., but about seven it rose from south west, and blew hard all night, and till ten next morning. At Philadelphia it was very calm and foggy all the evening, till about eleven, when the wind rose suddenly and violently from the south west, and blew a hurricane nearly all night, changing round to north west at four next morning. It is worthy of particular remark, that at Flushing the wind began to blow towards the point of greatest rain about four hours sooner than it did at Philadelphia, about one hundred miles more distant from the centre of the storm. This is in remarkable accordance with the fact detailed above, concerning the time the wind set in at Philadelphia from the south east on the morning of the 20th June, towards a very great rain which had been going on then for eleven or twelve hours at Silver Lake, and in that vicinity.

113. From all these facts, in connexion with those detailed in our previous reports, it is, we think, abundantly proved, that the air moves inwards towards the centre of great rains, and consequently upward in the region of the cloud. Nor is this inward motion difficult to account for. It has been long known that the barometer stands low in the middle of great storms, and nothing is more plain than that the air will run on all sides towards the point where the barometer stands lowest, with a velocity proportional to the square root of the depression. And as this air mounts upwards over the point where the barometer stands lowest, a condensation of the vapor must take place from the cold produced by diminishing pressure as it ascends. Now, the chairman of this committee has shown by calculation from acknowledged data, that for every pint of water which is formed by condensation of vapor, the cloud itself is expanded seven thousand six hundred pints by the latent caloric given out at the moment of condensation. Thus will the upward motion in the cloud be continued as long as air highly charged with vapor runs in below.

It is also easy to explain why the base of the cloud, during this rapid motion of the air upwards, remains nearly at the same level. For so long as the dew point of the air at the surface of the earth, which supplies the ascending column with vapor, remains the same, if the temperature of the air is the same also, it will have to ascend to the same height, before cold enough is produced by expansion to cause condensation of the vapor. This height is found to be about one hundred yards for every degree between the temperature of the air and the dew point, unless when the cloud becomes of great perpendicular depth, when the base sinks a little from the levity of the cloud.

The quantity of depression of the vapor as well as of the air, after due allowance is made for the fall of the dew point from the expansion, is nearly four hundred yards for a depression of the barometer one inch, on the supposition that the temperature of the air sinks 4° for a diminution of pressure equal to an inch of mercury.

A depression of near two and a half inches has been recorded in a spout accompanied with hail nine inches deep; hence the base of the cloud would descend in the centre near one thousand yards; and of course, if the dew point and temperature of the air were not more than 10° degrees apart, the cloud would reach the earth, and exhibit itself in the form of an inverted cone, expanding as it goes up, and by its rapid motion carrying up large drops of rain above the region of perpetual congelation, and throwing them out at the sides in the form of *hail.*

From the principles here developed, it will be easy, when a great storm springs up, or comes within disturbing influence, to tell in what direction it is raging; for the direction of the wind points it out.[1] The connection also between volcanoes and rains is no longer mysterious; for an upward

[1] An exception to the general principle of wind blowing towards the rain, was mentioned and explained in article 33.

motion of the air is produced and kept up by the volcano, the result of which must be a condensation of vapor, unless the dew point is very low. So powerful is this tendency, that in South America a dry season is sometimes changed into a rainy one, by the bursting out of a volcano. From these brief hints, we trust it will be acknowledged that something has been gained explanatory of the phenomena in question. But we must not stop here; it is not enough to know *where* it is raining at a given time, we must know *when* it will rain where we are. For this purpose it is of primary importance to know the direction in which storms move, and also their velocity in all the different seasons of the year.

We would suggest, as the most effectual, and perhaps the only, means of obtaining this end, an appropriation by government for the purchase of meteorological instruments, to be presented to those academies, schools, and colleges, that would pledge themselves to keep a journal of the weather, according to a prescribed plan, for five years; and send a monthly statement to a meteorologist, to be appointed by the government. If instruments were thus furnished for one hundred observers, it is altogether probable two hundred more would volunteer their services, knowing that their labors would be one hundred fold more valuable in combination with others than they had hitherto been.

With three hundred observers, properly located, no storm could spring up within, or enter the United States, without being constantly under the eye of at least two observers. And thus its extent, its progress, and the direction of the wind in its borders, would be fully known. Until this shall have been effected by government, we entreat every gentleman to whom the report is sent, to consider it a patriotic duty to furnish the means of enabling at least one faithful observer of the weather, to transmit a series of observations monthly, to William Hamilton, Esq., Actuary of the Franklin Institute, Philadelphia.

In closing this report, the committee tender their best thanks to the numerous correspondents who have favored them with regular records of the weather, and also to such as have returned answers to their interrogatories.

JAMES P. ESPY, *for Joint Committee.*

Report of the Committee on Meteorology to the Board of Managers of the Franklin Institute, embodying the facts collated by the Meteorologist relative to the storm of the 16*th*, 17*th and* 18*th March*, 1838.

114. As the great storm immediately preceding the vernal equinox of the present year was one of that class which is supposed to stretch over a wide extent of territory, and to traverse the globe with a determinate direction and velocity, it was believed that an accurate knowledge of its progress and violence at different points would not only prove highly interesting to the cultivators of meteorological knowledge, but would also tend much to the promotion of the object for which the committee was appointed; with this view the late Joint Committee on Meteorology, of the American Philosophical Society of the Franklin Institute, issued two hundred and fifty circulars to different parts of the United States and to Canada, asking for information on the various phenomena exhibited by the storm in the respective vicinities.

That the persons addressed might know the precise objects which the committee had in view, it was stated in the circulars, that the committee regarded it as highly important to ascertain the phases of the great storms of rain and snow which traverse our continent, their shape and size, what direction, and with what velocity their centres move along the surface of the earth, whether they are round, oblong, or irregular, in their shape, whether they move in different directions in the different seasons of the year, &c. &c.

To this circular between forty and fifty answers have been received, furnishing a mass of information highly useful and interesting.

These communications were placed in the hands of the meteorologist for collation, which duty he has performed, as will be seen by his report annexed.

Robley Dunglison, M. D.
Alexander D. Bache,
James P. Espy,
Charles N. Bancker,
John K. Kane,
Henry D. Rogers,
Sears C. Walker,
R. M. Patterson, M. D.
John C. Cresson,
Gouverneur Emerson, M. D.
Committee on Meteorology.

Philadelphia, July 9th, 1838.

To the Committee on Meteorology of the Franklin Institute.

115. Gentlemen, — The following facts comprise some of the most important details collected from the various correspondents. These, with additions from other sources, are arranged and numbered so as to commence in the westward, and progress towards the eastward.

1. Franklin, La. (S. W. of New Orleans) 29° 50′ N. 91° 50′ W. (From our regular correspondent, a lady.)

Beyond the storm. On the 16th, 17th, 18th and 19th of March, the wind was constantly from the N. high in the mornings, light in the evenings, except the 19th, when it was light in the morning. Clear from the 14th till the afternoon of the 22d. Slight frost on the 18th and 19th. Barometer rose from the 16th 30.20, till the 17th 30.30, and remained at that till the 20th, when it fell again to 30.20.

2. U. S. Hospital, Baton Rouge, La. 30° 29′ N. 91° 27′ W. Observed by W. R. Heipers, and communicated by A. Waddeir, Esq.

There was no storm here on the 16th and 17th of March, which were clear, fine days, wind strong from N. E. 18th fine, clear day, frost, wind light, N. W. 19th wind N. W. strong, cloudy.

3. Natchez, Miss., 36° 34′ N. 91° 25′ W. (From our regular correspondent, Henry Tooley, Esq.)

16th hazy, but without a cloud, wind N.	2	3	6		
17th hazy, very clear " N. W.	2	3	4	2	
18th not a stain on the ethereal blue " N.	2	W	1		
19th thick haze, " S.	2	SW.	2	1	

Barometer on the 16th	29.91
17th	30.03
18th	30.05
19th	29.95

4. Jackson, Miss., 32° 23′ N. 90° 8′ W. (Communicated by the Postmaster.)

There was no rain here from the 11th of March till April.

16th, wind's direction and force,	N.	2	6	3		
17th, " " "	NW.	2	3	4	2	
18th, " " "	N.	2	W	1		
19th, " " "	S.	2	SW.	1		

5. U. S. frigate Constellation, Pensacola Bay, lat. 30° 23′ 40″ N., long. 87° 12 W. (Observed by Dr. Hulse, and communicated by J. H. C. Coffin, Esq.)

This place was beyond the borders of the storm. On the 16th, 17th, and 18th of March, the wind was from W. N. W. to N. and N. W. constantly; generally moderate weather; clear, with haze in horizon.

On the 19th the wind was N. W. till noon, changeable P. M. to southwardly.

6. Huntsville, Alabama, 34° 36′ N. 86° 57′ W. (From John Allan, Esq.)

We had no storm here at the time mentioned. On the

15th, 16th, 17th and 18th of March, the wind was moderate from the N. W. Weather cloudy, with the exception of the 18th, which was clear. On the 19th the wind in the morning was a stiff breeze S. E., the remaining part of the day S.W.

7. Nashville, Tenn., 36° 10′ N. 86° 49′ W. (From our regular correspondent, MORGAN W. BROWN, Esq.)

March 14th, some rain, with change of wind from S. and and S. W. to N. W.

15th, cloudy, clouds passing from N. with moderate wind.

16th, cloudy, with slow rain in forenoon, and occasional showers in the afternoon, mixed with sleet; clouds passing from N. W. with brisk wind; becoming colder.

17th, clouds passing from N. W. and N., with brisk wind from N. W., partially clear at sunset and after night.

18th, clear, except cirri to E. in the morning, which soon passed off in that direction; wind brisk throughout the day N. W.; calm at night.

8. Grayville, Illinois. (From JAMES GRAY, Esq.)

The weather here on the 16th, 17th, 18th and 19th, was good, except that there may have been a little rain. The wind was, during that time, too gentle to be observed, and therefore I cannot say from what quarter it came.

9. Warren Court House, Illinois, on the Mississippi river, pretty high up, 40° 50′ N. 90° 50′ W. (From DANIEL MCNEILY, Esq., P. M.)

We had no storm here. The sky was remarkably clear, and fine weather on the days mentioned, if our memory serves us. On the night of the 15th we had a little snow, and for a few days after a light wind from N. W.

10. Logansport, Ind. (near northern part of the state,) 40° 53′ N. 86° 22′ W. (From D. D. PRATT, Esq.)

On the 16th, 17th, 18th and 19th of March, the weather here was remarkably fine and warm, and continued so till the 8th of April.

I recollect, however, on the night of the 15th, and during the forenoon of the 16th, a heavy damp snow fell to the depth of several inches, accompanied with a strong wind. I was riding down the Wabash in a direction a little south of west, and I think the wind was blowing nearly in my face. It might have been from a point 25° or 30° south of west.

11. Elizabethville, Harrison county, Ind. (From E. H. Compton, Esq., observed by John Low, Esq.)

March 16th, got up before sunrise, found a rainy morning, which early in the day changed to snow, and was attended with the severest storm felt here this season. The snow, notwithstanding the dampness of the ground, fell three or four inches deep. The storm continued till I went to bed, at 8, P. M.; wind from the N. N. W., the point from which it blew all day.

17th, left my bed at day-break, found it still cloudy, with considerable wind. It was partially clear through the day, and the wind came round to N. N. E.

18th, at day-break, found it clear, but somewhat cold; moderated, became pleasant, and remained so all day, and wind changed to E. S. E., quite calm.

12. Lexington, Ky., 38° 6′ N. 84° 18′ W. (From our correspondent, Prof. Robert Peter.)

	Bar.	Bar.	Bar.	Therm.			
16th,	29.02	28.97	29.00	45°	41°	36°	Rain, sleet, wind very high in the night N.W.
17th,	28.86	29.00	29.02	30	34	36	Snow, windy, north winds at night.
18th,	29.01	29.02	29.02	36	50	40	Clear, more clear.
19th,	28.98	28.88	28.85	40	65	57	Hazy, clear.

Rain 0.05 on night of the 15th.
" 0.40 on " 16th.
" 0.10 on " 17th.

Whole amount 0.55 of an inch.

The wind, if my recollection serves me, was at its height on the night of the 16th, N. W., and was still high on the 17th, N.

13. Wilmington, O. (a little north from Cincinnati,) 39° 30′ N. 84° 53′ W. (From A. Jones, M. D., by Hon. P. G. Goode.)

It commenced raining at noon on the 13th of March, and continued rainy until noon of the 16th, at which time it snowed and rained alternately. But a small quantity of rain fell. On the 17th, snow from a half to one inch deep. The wind on the 16th, 17th, 18th and 19th, was N. W., and a good part of the time a strong current. On the 17th and 18th, very strong current NW. W. The morning of the 18th was clear, and continued so till the 23d, at night, when there was a slight rain.

Troy, O. (80 or 90 miles N. of Cincinnati.) (From John G. Talford, Esq.)

On the night of the 16th of March, and also on the night of the 17th, we had a slight fall of rain and snow (mixed). The 18th was a clear, warm, and pleasant day, and I find noted, the honey-bee out this day for the first time. On the 16th the wind was N. W., not strong; and on the 17th and 18th it was N., gentle. The thermometer ranged from 26° to 70°.

14. Springfield, O., 39° 30′ N. 84° 50′ W. (From our regular correspondent, M. G. Williams, Esq.)

Began to rain at 6½, A. M., of the 16th March, changed to snow at 9, and terminated at night, 0.23 inch of water. Wind all day at N. 2, clouds N. N. W. 2. On the 15th the wind was N. W. 3-2 all day, and on the 17th it was N. W. 3 at 7 A. M., and at 2 P. M., N. N. W. 4; clouds N. 2, and at sunset N. N. W. 3; cloudy all day. 18th, clear; wind all day N. N. W. 2-3-1. The barometer was, on the 15th, 28.95, and fell to 28.86 on the morning of the 17th, at which it stood all day, and rose again on the 18th to 28.90, but fell very rapidly on that day to 28.63.

15. Greenfield, Ind. (near the middle of the State,) 39° 53′ N. 85° 52′ W. (From our regular correspondent, David Alter, Esq.)

March 15th, cloudy; light breeze from N. W. and occasionally a sprinkle of rain. 16th, breeze from the N. and some snow falling. 17th, clear, strong wind from N. 18th, clear, light breeze from N.

Rome, Ind., 37° 58′ N. 86° 32′ W. (60 miles S. W. of Louisville.) (From Samuel Frisbie, Esq.)

We had no storm of rain or snow during the days named. Indeed, previous to the 6th of April, we had no rain for a long time, and the Ohio bottoms became very dry and hard to plough. I must say, however, I took no note of the weather, and I rely solely on my recollection.

16. Washington, Michigan. (From D. Cooley, Esq. P. M.)

March 15th, cloudy. 16th, snowed moderately through the day; amount of snow two inches; wind brisk from N. E.; clear at 9, P. M. 17th, 18th and 19th, clear; wind not noted.

Centreville, Michigan, (southern part of the state, and nearer the west than the east.) (Observed by William Connor, Esq., communicated by J. W. Lawley.)

March 16th, at 4½, A. M., commenced snowing, heavy wind N. W. — cold — at noon stopped snowing; depth of snow two inches. The 17th, clear and pleasant; snow gone at noon. 18th, clear and warm. 19th, thermometer 66° in the shade.

17. Western Reserve College, Hudson, O., (N. E. corner). (From our correspondent, Prof. Elias Loomis.)

March 15th, dense drizzling fog, wind faint from N.

W. 16th, wind light from N. W. to N. N. W., with some snow and drizzling. 17th, wind fresh in the morning, strong in the afternoon from N., varying from about N. N. W. to N. E., (March wind.) 18th, perfectly clear and bright; wind light from N. N. W. to N. The barometer was nearly stationary on the 16th and 17th, at about 28.86; on the 18th it fell to 28.79, and on the 19th to 28.47.

18. Jefferson, N. C., (north west corner of the state,) 36° 30′ N., 81° 20′ W. (From R. Murchison, Esq.)

The storm commenced here some time in the night of the 15th of March, with rain strongly driven by W. and N. W. winds, and terminated on the 18th in the afternoon. The wind blew with little variation from W. and N. W. much of the time with great velocity.

There was considerable rain on the night of the 15th and on the morning of the 16th; and about noon on that day a furious storm of snow commenced, that continued till about (or a little before) twelve, M., on the 18th. The whole of the 17th was the most constant and violent snow storm I ever saw to continue so long.

It is difficult to state the precise depth of the snow. I presume it would have averaged say eighteen or nineteen inches deep, if the wind had not blown so as to drift it.

It was very cold during the storm; range of mercury, from 25 to 8 above zero.

19. Charleston, S. C., 32° 47′ N., 79° 57′ W. (From our correspondent, Edward C. Keckeley, M. D.)

March 16th, wind south — rain.
17th, wind south — cloudy.
18th, wind N. W. — fair.
19th, wind N. W. — fair.

The rain of the 16th was very trifling. Since then to this time, (3d of April,) we have had no rain. During the whole of the month of March, we have had very little wind; indeed, the atmosphere has been close and sultry.

20. Newbern, N. C., 35° 20′ N., 77° 5′ W. (From William G. Bryan.)

Clear, and pleasant, and calm, on the morning of the 16th. Light wind in the afternoon at S. On the 17th, cloudy and warm. Light rain before day, wind at S. Afternoon cold and cloudy — rain and hail — wind W. On the 18th, cold and cloudy, moderate wind at N. W. The 19th was clear and cold, moderate wind W. 20th, very pleasant — smoky — wind S. W.

21. New Garden, N. C., (eight miles N. E. of James Town,) 34° 57′ N., 79° 10′ W. (From Jonathan L. Slocum, communicated by David Lindsay, Esq.)

On the 16th, the weather was cloudy and damp during the day, in the evening some thunder and rain; wind N. E. all day. On the 17th, cloudy in the morning, and in the afternoon and evening rain falling, mixed with snow; wind N. E. On the 18th, wind N. W. till evening, then N. E. — cloudy — snow nearly two inches deep. 19th, wind N. W. all day, clear and pleasant.

Smithville, N. C., (S. E. corner of the state,) 34° 7′ N., 78° 10′ W. (From G. S. Jewett, Esq.)

March 16th, clear and fine; wind S. W., probably light. 17th, clear, cold and windy, W. S. W.. 18th, cold, a little rain, windy, N. W. Also, twenty miles above Smithville, March 16th, pleasant day; wind S. W., very fresh about one, P. M. 17th, wind not high this day. 18th, not known. 19th, wind N. W., pleasant.

22. Alexandria, D. C., 38° 49′ N., 77° 4′ W. (From our correspondent, William E. Harper, Esq.)

The storm commenced on the 16th, and terminated on the evening of the 18th.

The wind blew constantly from the N. E. strong on the 16th, 17th and 18th, and there was considerable rain, snow, and hail on the 17th, continuing till noon of the 18th.

On the 19th, wind strong from N. W. The thermometer at freezing point before sunrise.

23. Capitol Hill, Washington City, 38° 53′ N., 77° 2′ W. (From our correspondent, Dr. J. M. Foltz, of U. S. Navy.)

The wind on the 16th of March was S. E., and light. On the 17th, a strong gale from N. E. On the 18th, N. E., fresh, and on the 19th, N. W., moderate.

At nine o'clock, on the 17th, it was raining, and had rained $1\frac{1}{100}$ inch; it rained and snowed two inches on the 17th, and on the 18th, $\frac{8}{10}$ inch more; making in all 3.81 inches. The barometer was stationary on the 16th at 29.93. It fell by nine A. M. of the 17th, to 29.758, and at three, P. M., it was down to 29.60, and was the same next morning.

Dr. Foltz infers, from the great severity of the storm, and from the quantity of rain and snow accompanied with a strong N. E. gale, that he was, at Washington, in the centre of the storm.

24. St. John's College, Annapolis, Md., 20° 0′ N., 76° 43′ W. (From our regular correspondent, Prest. H. Humphrey.)

The storm was of great violence, and as far as I know, blew steadily from the N. E. When I rose on the morning of the 17th of March, it was raining moderately, and I observed the barometer had fallen from 30.00 to 29.76. It continued to sink all day, and at 6, P. M., was 29.62, and on the morning of the 18th, at seven, was 29.59.

My opinion is, that the wind began to blow about 11, P. M., of the 16th, at which time I observed a remarkable light, due E., that I took to be an aurora. I watched it for some time after my lamp was extinguished, and it exhibited vivid pencils, as high as 45° or 50°, and cast a strong light, although obstructed by broken clouds. It was soon after this that I noticed the raising of the wind, by its effect on the building. The rain on the 17th turned to snow in the afternoon, which continued through some part, or all of the night, but the quantity was small, leaving but two or three inches on Sunday at noon. The rain fell in torrents, and the gale blew at times as powerfully as I have ever felt it at this place. Its violence abated somewhat on Sunday afternoon.

25. Gettysburgh, Penn., (south side of the state.) (From our regular correspondent, Jacob Lefever, Esq.)

The storm commenced with dribbling of rain at half past ten P. M. March 16th, and the heavy fall of snow terminated about half past nine, A. M., on the 18th, although there were frequent showers of fine snow till about half past five, P. M. The morning of the nineteenth was very nearly clear and calm. The wind was N. N. E., that is, nearer north than north east, all the time. It commenced with rain: but on the morning of the 17th, the snow was three-fourths of an inch deep, and melting very fast. The whole quantity fallen I calculated at 1.7473 inches. The snow along the mountain, within ten miles of this place, was said to have been at least two and a half feet deep.

The wind was from 2 to 3 from the evening of the 16th till the evening of the 18th. That is, a strong breeze.

26. Bellefonte, Penn. (near the centre of the state,) 40° 54′ N. 77° 47′ W. (From our regular correspondent, John Harris, M. D.)

The snow commenced at ten, P. M., of the 16th, and continued till four, P. M. of the 18th, being a great part of the time mixed with rain; its depth about seven inches — whole quantity estimated at 1.5 inches of water.

The wind was north at seven A. M. of the 16th and gentle; from two, P. M., of the 16th, till seven, A. M., of the 19th, the wind was constantly very gentle from N. E., when it changed to S. W. Barometer all day of the 16th, 29.29; at 7, A. M., of the 17th, 29.25; at 2, P. M., 29.24; at 9, P. M. 29.20.

27. Meadville, Penn., 41° 38′ N., 80° 10′ W. (From our regular correspondent, FREDERICK HUIDEKOPER.)

	Thermometer.			Barometer.			Direction & force of wind.		
Day.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M
16,	33°	36½°	29°	$\frac{0}{28\ 85}$	$\frac{0}{28.85}$	$\frac{0}{28.85}$	N. 1	N. 2	N. 4
17,	29	34	33	$\frac{0}{28.83}$	$\frac{0}{28.83}$	$\frac{0}{28.84}$	ENE. 4	E. 5	E. 3
18,	27	45	27	$\frac{10}{28.82}$	$\frac{10}{28.81}$	$\frac{10}{28.77}$	ENE. 4	ENE. 5	0

On the 16th, snow too slight to be mentioned.

28. Rochester, N. Y., 43° 8′ N., 77° 51′ W. (From JOHN B. ELWOOD, Esq.)

	10 o'clock, A. M.				10 o'clock, P. M.			
	Ther.	Bar.	Wind.	Sky.	Ther.	Bar.	Wind.	Sky.
15th,	48°	29.60	S.	Cloudy.	40°	29.60	W.	Cloudy.
16th,	37	—.70	NE.	do.	32	—.75	NE.	do.
17th,	36	—.80	E.	Fair.	37	—.75	E.	Fair.
18th,	43	—.65	E.	do.	34	—.50	NE.	do.
19th,	35	—.30	W.	do.	43	—.35	E.	Cloudy.
20th,	32	—.30	NW.	Cloudy.	38	—.60	NE.	do.
21st,	34	—.70	NW.	Showers.	50	—.60	SW.	Showers.

The winds were at no time very strong, or a note would have been made of it.

29. Onondaga Hollow, N. Y., (middle of the State,) 43° 0′ N., 76° 6′ W nearly. (From J. L. HENDRICK, Esq.)

We had no storm here except a small snow storm on the afternoon and evening of the 16th of March; the wind N. W. all day. On the 17th, the wind somewhat variable, generally N., (A. M.) and N., N. N. E. and N. E., (P. M.;) cloudy all day. On the 18th, wind N. and N. N. W. (A. M.) and N. W. (P. M.) day cloudy. On the 19th, wind variable, but generally W.; day fair. The strength of the wind during those days was also variable; sometimes, and especially from the W. and N. W.; rather strong, at other times only a gentle breeze.

30. Silver Lake, Penn., 41° 55′ N., 76° W. (From our regular correspondent, a lady.)

	Thermometer.			Barometer.			Winds.		
Day.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M	2 P. M.	9 P. M.
16,	36°	38°	36°	$\frac{0}{28.00}$	$\frac{0}{27.98}$	$\frac{0}{27.98}$	SSE. 2	S. 3	S. 2
17,	32	38	34	$\frac{0}{28.00}$	$\frac{0}{28.00}$	$\frac{0}{28.00}$	NW. 2	NW. 2	NNW 2
18,	31	42	58	$\frac{10}{28.00}$	$\frac{10}{28.00}$	$\frac{10}{28.00}$	NW. 1	NW. 2	NW. 3

On the night of the 16th it snowed one inch deep, and on the 17th, it snowed half an inch.

31. Sunbury, Penn., 40° 53′ N., 79° 50′ W. (From our regular correspondent, HUGH BELLAS, Esq.)

	Thermometer.			Barometer.		
	8 A. M.	Noon.	5 P. M.	8 A. M.	Noon.	5 P. M.
16th,	41°	49°		29.45		
17th,	34	37	36°	29.45	29.45	29.45
18th,	32	38	36	29.30	29.30	29.30

On the night of the 16th snow six inches deep; on the mountains between this and Pottsville, three or four feet deep — no mails for seven days.

Snow, rain and snow, on the 17th, and on the morning of the 18th, the wind N. E., on the 16th, 17th, and 18th, except at eight A. M. of the 17th, when it was E. On the 19th changeable from N. W. to S. W.

32. Bucks County Academy, Penn., 40° 17′ N., 75° 7′ W. nearly. (From our regular correspondent, Prof. L. H. PARSONS.)

	Thermometer.			Barometer.			Winds.		
	7. A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
16th,	44°	56°	43°	$\frac{29.92}{1}$	$\frac{29.82}{2}$	$\frac{29.81}{0}$	NE. $\frac{1}{2}$	NE. $\frac{1}{2}$	NE. $\frac{1}{2}$
17th,	37	35	33	$\frac{29.87}{0}$	$\frac{29.81}{0}$	$\frac{29.73}{0}$	NE. $\frac{1}{2}$	NE. 2	NE. 3
18th,	$32\frac{1}{2}$	$34\frac{1}{2}$	33	$\frac{29.60}{0}$	$\frac{29.65}{0}$	$\frac{29.65}{0}$	NE. $2\frac{1}{2}$	NE. 1	NE. 1

It rained on the night of the 16th; depth of snow, five inches in all; ceased on the night of the 17th. Snow and rain, 2.48 inch water.

33. Reading, Penn., 40° 18′ N., 75° 55′ W. (Observed by C. F. Egellmann, Esq., communicated by Samuel Ritter, Esq.)

March 16th, cloudy, with N. W. wind at 2, P. M. Temperature, 62°, 17th, rain at 7, A. M., turning to snow at 7½; snow continued, with occasional rain, till the morning of the 18th, wind strong from N. E. all the time; in the evening it changed round to N. W. and was N. W. and W. next day. On the 17th, the thermometer was from 34° to 33° all day.

34. Philadelphia, Penn. 39° 57′ N., 71° 11′ W. (By James P. Espy, Meteorologist of Joint Committee.)

March 16th, wind very gentle N. and clouds from S. W. 1, and cloudy at 7, A. M.; wind got round to N. E. 1 before 2, P. M., clouds still coming from S. W. 2; a slight sprinkle of rain at 9, P. M.

17th. On the morning of the 17th, at 7, it began to rain, mingled with hail; it rained much during the morning, and snowed much in the afternoon, wind and clouds from N. E.; storm increasing in violence all day, and continued very violent all night, until 9, A. M., of the 18th, when it began to abate, and at 1, P. M., it had nearly ceased snowing; wind still very strong N. E. A little snow in the afternoon, and by 6, P. M., the wind had veered round to N. by E., and gradually died away in the night; and on the morning of the 19th it was, with the lower clouds, N., very gentle, and the upper clouds from the west moving quite slow.

The barometer was stationary on the 16th, at 29.91, and fell on the 17th, from 29.93 at 7, A. M., to 29.78 at 9, P. M., and was at its lowest, 29.68, on the next morning. The thermometer ranged from 44° to 55° on the 16th, from 37° to 33° on the 17th, and was only 33° at 2, P. M. The dew point was 38°, or 17 degrees below the temperature of the air on the 16th at 2, P. M.; and at 2, P. M. of the 17th, it was almost the same as the temperature of the air itself, or 33°.

Greendale, Penn., (west of the centre of the state). (From our regular correspondent, H. B. Wright, Esq.)

March 16th, calm, clouds from N., small rain P. M., cloudy all day. 17th, calm till 11, A. M.; snow all day and all night till 9, A. M., of the 18th, clearing at 6, P. M., with fog in the night.

Wind N. E. on the 17th, calm again on the 18th, warm on the 20th, with high waters. Whole quantity of water deposited, 68.100.

35. Snow Hill, Md., (Eastern Shore, southern part,) 38° 10′ N., 75° 25′ W.

On the morning of the 16th, appearances of rain; at 4, P. M., raining, wind nearly calm, N. E. On the 17th, at 8, A. M., rain, wind E. N. E. 4; it rained all day, wind N. E. 5, and continued to blow hard all night, frequently raining hard. Towards day on the 18th, it became moderate, and at 11, A. M., wind was N. 4, still cloudy and dark; at 5½, wind N. 4, rain, mixed with snow. On the 19th, in the morning, the wind was west, and moderate; at 4, P. M., it was northerly and clear.

36. Log-book of ship Algonquin, near Delaware Capes.

March 16th, noon, civil reckoning,— light airs from W. S. W., and clear; at 1, P. M., calm; at 6, P. M., light airs from E.; sounded in fifty fathoms water; midnight, strong breezes from E. by N., and hazy; at 4, A. M., strong breezes and rain, 35 fathoms water; at 5, took in top gallant sail, double reefed the mizzen top sail; at 7, double reefed the fore and mizzen top sail, took in the jib; at 8, strong gales, and thick, rainy weather, 18 fathoms water; wore ship's head to S. E. [to avoid coming on shore]; at 11, A. M., gale E. N. E. increasing, moderately strong, and a high sea, raining very heavy; sounded 22 fathoms water; continuing with strong gales N. E. by. E.; heavy squalls and torrents of rain; bearing a heavy press of canvass to get off shore; at 4, P. M., took in main sail; 23 fathoms water; at 6, P. M., 30 fathoms water; took in fore top sail; *at ten minutes past* 6, *fell start calm;* left a very heavy sea; midnight *calm;* cleared off, very heavy swell. At 2, A. M., of 18th, light air from south, set the fore sail and fore top sail; shut in thick; at 4, A. M., light airs and thick weather; at 5, A. M., set single reefed top sails, jib, and spanker main sail, wind still south; at 8, set the top gallant sails; thick weather; noon, moderate breezes, wind baffling.

Batavia, N. Y., (near N. W. corner of the state,) 42° 58′ N., 76° 20′ W. nearly (From W. H. Webster, Esq.)

Wind on the 16th, 17th, and 18th of March, fine acicular crystals of snow falling all day of the 16th, but now lying on the ground. Sun seen through the clouds all day on the 17th.

37. Catskill, N. Y., 42° 10′ N., 73° 52′ W. (From the Postmaster.)

Between the 16th and 19th of March, about three inches of snow fell; wind southerly at first, soon veering about S. E., N. and N. W.; a heavy gale on the 18th and 19th, wind northerly.

38. Pottsdam, N. Y., 44° 38′ N., 74° 59′ W. (From David S. Shelden, communicated by H. Allen, Esq., P. M.)

March 16th, wind all day N., with a little snow in the morning. On the 17th, cloudy in the morning, clear in the afternoon; wind all day N. E., light. On the 19th, clear in the morning, a little rain in the afternoon; wind N. E. in the forenoon, and S. W. in the afternoon, very light.

39. Montreal, Canada, 45° 31′ N., 73° 35′ W.

From the journal of James McCord, Esq. it appears that it neither rained nor snowed here during 16th, 17th, 18th, 19th, or 20th of March, and the wind blew steadily, but not violently, from the north, on the 16th, 17th, 18th, and 19th, and on the 20th shifted to the N. W.

The barometer stood as follows:

16th,	morning,	30.040	evening	30.124
17th,	"	30.250	"	30.200
18th,	"	30.088	"	29.890
19th,	"	29.678	"	29.464
20th,	"	29.724	"	29.750

The mean of the maximum and minimum of the thermometer, during those days, was 31° and 8°.

The mornings were generally clear and fine, growing cloudy towards the evening. The strength of the wind may be called a *fresh breeze.*

40. University of Vermont, Burlington, 44° 30′ N., 73° 12′ W. (From Prof. George W. Bluedict.)

There was no storm here of any kind during the days in question. The whole month of March, previous to that time, was remarkable here for its mild and quiet character. East winds are almost never known here. Though I made no record of the wind on the days mentioned in the circular, I am confident that the set of the air (quite slight) was from the south, and the weather pleasant.

41. Charlestown, N. H., 43° 14′ N., 72° 25′ W. (Dr. S. Webber.)

March 16th, wind N. E., cloudy, broke away partially for a little while about noon, showing many broad streaks of cirro-strati; in the afternoon, sky again overcast, looking like rain, Therm. 34°.

17th, wind N. E., cloudy through the day; at noon wind became E., but changed again to N. E., Therm. 36°.

18th, wind N. E., fresh and raw; about 11, A. M., began to snow, which continued moderately through the day, Therm. 29°.

42. Jafrey, N. H., (S. W. corner of the state,) 42° 45′ N., 72° 5′ W.

L. Howe, Esq. informs us that there was no storm there; only one inch of snow on the 18th, at noon, fair on the 19th. On the 16th and 17th, wind not recollected.

43. Wesleyan University, Middletown, Conn. 41° 34′ N., 72° 39′ W. (From our regular correspondent, Prof. Aug. W. Smith.)

On the morning of the 16th, at half past seven, A. M., the wind was noted N. W., the rest of the day, N., quite gentle. On the 17th, wind N. at half past seven, A. M.; and clouds N. E.; at twelve, meridian, and half past five, P. M., wind E., and gentle all day; cloudy, with slight rain at two, P. M. On the 18th, snow about two inches deep all the morning; time of beginning not mentioned; wind N. E. all day, and strong. 19th, wind N. E., A. M., strong, and N. W., P. M., gentle. Barometer rose from 29.81 on the morning of the 16th, to 30.11, at half past five, P. M. of the 17th; fell again till half past five, P. M., of the 19th, when it was 29.70.

44. Newport, R. I., 41° 28′ N., 71° 21′ W. (From our regular correspondent, R. J. Taylor, Esq.)

March 16th, wind N. W. in the morning, and S. W., P. M. 17th and 18th, and morning of the 19th, N. E.; then N. W. at two, P. M., and S. W. at nine, P. M. — *heavy on the 17th.*

	7 A. M.	2 P. M.	9 P. M.
March 16th, Barometer	29·65 / 10	29·72 / 10	29·80 / 0
17th, "	29 90 / 0	29·90 / 0	29·86 / 0
18th, "	29·67 / Snow	29·57 / 0	29·51 / 0

Snow from six to twelve inches on the 18th.

45. Brown University, Providence, R. I., 41° 50′ N., 71° 25′ W. (From our regular correspondent, Prof. Alexis Caswell.)

	Barometer.			Thermometer.		
	S. R.	1 P. M.	10 P. M.	S. R.	1 P. M.	10 P. M.
March 17th,	29.90	29.96	29.91	35°	38°	34°
18th,	—.74	—.70	—.60	31	32	28
19th,	—.74	—.45	—.41	28	38	34

	Winds. S. R.	1 P. M.	10 P. M.	Weather. S. R.	1 P. M.	10 P. M.
March 17th,	N. E.	N. E.	N. E.	var.	cloudy.	cloudy.
" 18th,	"	"	"	snow.	snow.	snow.
" 19th,	"	easterly.	easterly.	cloudy.	cloudy.	clear.

The 15th was mild and pleasant—16th do. and wind came to N. E. A. M.; on the 17th wind N. E. brisk and raw, increasing towards night and cloudy. Wind heavy during the night.

On the 18th, snow began to fall about six, A. M., wind heavy N. E., snow continued till after ten P. M. but ceased before morning. The wind was so violent during the storm, that the snow was considerably drifted; quantity half an inch water.

46. **Dedham, Mass., 42° 15′ N., 71° 11′ W.** (Journal of Mr. Talbot, communicated by Elisha Thayer, Esq.)

16th, fair, moderate N. E. wind.
17th, cloudy, strong N. E. wind.
18th, cloudy, very strong N. E. wind with 2½ inches snow.
19th, cloudy, moderate N. W. wind.

47. **New Bedford, Mass., 41° 17½′ N., 70° 56′ W.** (From Richard Williams, Esq.)

	Ther.	Bar.	Wind.		Weather.
16th, sunrise,	37°	30.00	NW.	light.	clear.
2 P. M.	49	30.09	NE.	mod.	clear.
9 P. M.	41	30.18	"	"	cloudy.
17th, sunrise,	37	30.23	"	fresh.	"
2 P. M.	40	30.29	"	"	"
9 P. M.	35	30.26	"	high.	"
18th, sunrise,	34	30.11	"	"	beginning to snow.
2 P. M.	33	29.99	"		snowing lightly.
9 P. M.	33	29.91	"	fresh,	cloudy, water fallen .60
19th, sunrise	32	29.78	NNE.	"	light snow.
2 P. M.	36	29.71	N.	mod.	clouds broken, P. M. clear.
9 P. M.	32	29.74	westerly,	light.	clear.

Northborough, Mass., 42° 16′ N., 71° 48′ W., nearly. (From JOSEPH ALLEN, Esq.)

March 16th. This was a mild, pleasant day, wind S. W.; some time during the night the wind shifted into the N. E.; and the 17th was raw, cold and cloudy — wind pretty strong from N. E. Early on the 18th, the snow began to fall, and the wind to rise; and through the day the storm continued without intermission, though its violence abated somewhat in the latter part of the afternoon. The snow was quite moist, yet so great was the violence of the wind, that it drifted a good deal, probably about six inches in depth.

Williams College, Mass., (N. W. corner of the state,) 42° 30′ N., 73° 12′ W.

President Albert Hopkins states that from the 16th to the afternoon of the 17th, the wind was N. W.; and then changed to N. E.; that it commenced snowing soon after breakfast on the morning of the 18th, wind N., or perhaps a little E. of N. On the 19th, it was from N. to N. W., and clear. The thermometer varied only from 30.5° to 39° till the 19th, when it rose to 43°, wind very light.

48. Concord, N. H., 43° 12′ N., 71° 29′ W. (From JOHN FARMER, Esq.)

The storm was hardly felt here. The weather was cloudy all day, on the 17th of March with the wind E. and N. E. On the 18th a light snow commenced at noon, and continued through the afternoon, enough to cover the ground.

The wind was brisk part of the day, from the N. E. The highest point of temperature during the day was 33°, and the lowest 28°.

On the 19th, at 9, A. M., all appearances of a storm had ceased, wind N. W. as it had been on the 16th.

The thermometer stood as follows:

	6, A. M.	Highest.	9, P. M.
16th	33°	54°	43°
17th	36°	43°	35°
18th	33°	33°	28°
19th	28°	50°	38°

49. Bethlehem, N. H., 44° 20′ N., 71° 35′ W.

William Kenney, Esq., informs us that there was no storm here, the weather was mild and pleasant till the afternoon of the 18th, when there was a very little snow; the wind was very little, westwardly.

50. Portland, Maine, 43° 39′ N., 70° 20′ W. (From the Diary of Lemuel Moody, Esq.)

March 16th, from morning to noon, light N. E. airs and clear weather. P. M. clear, calm, warm and pleasant. Thermometer at sunrise 34°, noon 46°, 8, P. M., 40°.

17th, from sunrise to noon, clear weather, with light N. E. airs. P. M. cloudy, with light S. E. airs, inclining to calm.

Therm. 30° 38° 32°

18th, forenoon brisk wind, varying from E. N. E. to N. E. with thick, cloudy weather, particularly so in the south quarter. At half past 1, commenced a moderate N. E. snow storm, wind not more than a brisk gale. Snow fell very moderately and ceased the first part of the evening, snow 1½ inches deep.

Therm. 30° 30° 26°

19th, forenoon moderate N. E. winds and cloudy. P. M. light winds from E. round to S. Evening clear, calm and pleasant.

Therm. 28° 45° 38°

The foregoing furnishes a summary of the information received concerning the storm, both from our regular correspondents, and in answer to the circular issued by the joint committee.

The following facts, chiefly collected from the newspapers of the day, will be found highly interesting in connection with those already given.

From the American Sentinel, March 23.

Arrived at Philadelphia, March 23d, packet ship Algonquin, having been 11 days to the N. of Cape Hatteras. On the 17th, at 8, A. M., Cape Henlopen bearing N. W., distant 15 miles, took a heavy gale E. by N.; hauled off. On Sunday, the 18th, lat. 37° 50′, spoke brig Venus, for New York, who had lost two men and jib-boom by gale on day previous.

From the Mercantile Advertiser of the 19th of March. 40° 42′ N., 74° 1 W.

The wind on the 17th and 18th was heavy, N. E., accompanied with snow. Of course nothing got to sea from New York, and but few vessels arrived.

From the same paper, of the 20th March.
Lewis, 38° 35′ N., 75° 12′ W. (Correspondence of Philadelphia Exchange.)

March 16th. Wind now at E. and weather very lowery.

March 17th, 2, P. M. The schooner Samuel McDowel, and shortly after the schooner Richmond, came on our beach, the wind E. N. E., and blowing a heavy gale.

Morning of the 18th. The Richmond has gone to pieces. From 4 till after 12 last night, the wind blew with great violence, and the sea made considerable breaks over the breakwater.

From the same paper of the 24th.

A number of outward bound vessels are detained, owing to the E. winds which have prevailed some days.

From the same paper of the 26th.

Schooner William, off Cape Hatteras, N. 35° 14′, W. 75° 30′, on the 19th, in a gale W. N. W., lost the deck load.

From the National Gazette of the 20th.

Cape Island, March 18th. I cannot describe to you the horrors of last night. The rain fell in torrents, and the wind, N. E., blew such a gale that it baffles all description. On yesterday afternoon the wind was increasing, with rain, hail, and snow.

From the Commercial Herald and Pennsylvania Sentinel of the 20th.

Norfolk, 36° 51′ N., 76° 19′ W., 18th March. The wind continues from N. to N. E. It rained nearly all day, yesterday, the 17th.

From the same paper of the 22d.

Fifteen schooners at Little Egg Harbor dragged their anchors.

From the same paper of the 27th.

Arrived, ship Sabina, 50 days from Rio de Janeiro. Had been off the Capes of Delaware in thick fog from the 21st. Experienced tremendous gales from W. S. W. on the 17th and 18th March.

From other papers not recollected.

Schooner Caroline, in a gale on the 18th, lat. 40° 24′, long. 72° 12′, lost a man overboard.

Brig Russel, lat. 38°, long. 73°, lost stern boat and davits on the 18th, during a severe N. E. gale.

Packet ship North America arrived at New York on the 18th. She had to heave too from Sunday morning till Monday morning, (that is, from the 18th till the 19th) during which time it blew a gale E. N. E. outside the Hook.

From the Baltimore American of the 20th.

The fall of snow on the 17th and 18th, was deeper to the west than at this place. The mail carriage, which was despatched from Frederick, west, with eight horses attached to it, was so effectually impeded by the snow, that the driver was compelled to return to Frederick. The snow on the Alleghanies, some days ago, was two feet deep along the turnpike, from Cumberland to Wheeling, and the mails were carried through with the greatest difficulty.

From the United States Gazette of the 21st.

Packet ship Pochahontas rode out the gale of Saturday night, the 17th, off the light-house, on the Brandywine shoal. At one time the gale was so violent, that it was feared her masts would have to be cut away.

The same paper of the 22d states, from the Delaware breakwater, that the gale was the most severe ever experienced at that place.

James P. Espy, *Meteorologist.*

Condensed Statement of the Facts.

116. It appears from the facts detailed in the report of the committee on meteorology, that a storm of rain and snow of great violence was raging on the 17th of March, reaching north east and south west from the western extremity of North Carolina to the northeastern extremity of Pennsylvania; and in a north west and south east direction, from about the middle of Ohio, to the eastern extremity of North Carolina, and east and west from beyond Lexington, Kentucky, to some distance in the Atlantic beyond the eastern shore of Maryland. The storm was much the greatest on the 17th, and its boundaries on this day about noon, have been represented by the middle circle in the map accompanying the report of the committee.

This storm moved along the surface of the earth nearly towards the east.

It appears that the barometer fell on the 17th, in all places near the centre or far within the boundaries of the storm, and rose in many places near its borders, and beyond them; especially in the extreme west and north east, (see Lexington, and Montreal, and Providence, and Middletown.)

It appears, also, what might naturally be expected from the fall of the barometer within the storm, that the wind at the borders, and for some distance beyond, blew inwards, towards the storm. The information which we have at present does not enable us to know whether the barometer stood lowest in the very middle of the storm or not. If it did, and there was no general currents in the atmosphere to produce oblique forces, the laws of dynamics justify us in expecting the wind in such case to blow *inwards* from the circumference, exactly towards the centre, just as we would expect the wind to blow outwards *from* the centre of a storm, if there was any cause in nature to make the barometer stand constantly higher at that point than in the circumference.

By casting the eye on the map accompanying the report, it will be seen that there is no one point at which all the arrows, if prolonged, would meet. There is, indeed, much irregularity in this respect. For example, the arrow near Jamestown, North Carolina, which is south of the centre of the storm, still shows the wind north east; as if the point of greatest depression of the barometer, was near the southern border of the storm; somewhere in North Carolina; while in the northern part of the storm, the arrow for Silver Lake shows the wind to be north west; as if the point of greatest depression of the barometer was near the north part of the storm.

And yet, if the strong winds be considered in the extreme boundaries of the storm, for example, Springfield and Wilmington, in Ohio, and in the east (all the observations from the Chesapeake to New York,) these arrows being prolonged will meet very little south of the centre of the storm; and, as these winds were all strong and steady, for many hours, and were under the *general* influence of the whole storm, and not affected by any *particular* localities, they speak a language which cannot be mistaken.

The wind could not blow thus strongly inwards for many hours without moving upwards in the centre of convergence, whether that was the centre of the storm or not; and as the barometer continued to fall in the region of the storm during the whole day, the air must have flowed outwards from the region of the storm *above*, even faster at first than it flowed inwards *below*, otherwise the barometer would not have fallen within the storm.

The storm was so nearly round on the 16th and 17th, that it would be an affectation of accuracy beyond our data, to give any other figure in the topographical chart. It was also so nearly the same size on each of those days that it is impossible to say on which day it covered the largest territory; the quantity of rain and snow known on the 16th was small, while that on the 17th was very great. But on the 18th, it greatly increased its size, (if it remained round,) for on that day its diameter from south west to north east, along our coast, was more than six hundred miles, reaching from North Carolina to Maine. Whereas on the two preceding days it was only about five hundred in diameter.

From the 16th to the 17th, the storm travelled towards the east or even a little south of east; for on the 15th, there was considerable snow in the southern part of Michigan, and on the night of the 16th, and on the 17th, there was very little snow at Meadville, Pennsylvania, though Meadville is on a lower latitude. But on the 18th, the storm manifestly moved towards a point north of east, for, at half past one, P. M., it began to snow in Portland, Maine, 2° further north than it extended while in Pennsylvania.

Whether this extension of the storm further north, depended on the direction in which its centre was moving, or on a general widening out of the storm, cannot be determined; as its southern boundaries on that day are not strictly defined by the facts collected. It certainly extended down to lat. 38° in long. 73°, wind still north east. And there were strong gales W. S. W., about that time, from lat. 31° to lat. 34°. Though the packet ship Algonquin, in lat. 37° 50′, (longitude and time of day not given,) says nothing of the storm of that day, but speaks of the one on the day before, it would be extremely desirable to know what her log book says of the storm after she took the gale east by north, near the Delaware Capes, at eight, A. M., of the 17th, and then hauled off. As she went to the south, her log would probably be able to answer a very interesting question, which our present information leaves undetermined. *In what direction and with what force did the wind blow on the south east side of the storm on the 17th?* [1]

116. This storm travelled with a velocity of about eighteen and one third miles an hour from beginning to beginning. It was just one day in reaching Philadelphia, after it commenced in Springfield, Ohio; a distance of about four hundred and thirty-five miles, and a comparison with other points agrees well with this.

There is one *apparent* anomaly worthy of particular notice. On the N. N. E. of the storm, eighty or one hundred miles beyond its extreme boundary, there is a region from which the wind seems to have blown outwards in all directions.

Albany seems to be included in this region — and if it shall be found that at Albany and the towns near it, or perhaps as far West as Utica, the barometer rose considerably on the morning of the 17th, one step will be made in the

[1] Any further information concerning this storm will be gladly received. If every person keeping a journal of the weather within and for some distance beyond its boundary, would send a copy of it for the 15th, 16th, 17th, and 18th March, the apparent irregularities of this storm would probably be explained.

explanation of this phenomena, whatever may be the cause of this rise.

But the most remarkable irregularities of all, will be found at Meadville, Penn., and Lexington, Ky.

Here the wind seemed to blow almost in a tangent to the storm. There is an irregularity somewhat similar to this on the south east side of the storm at New Garden, North Carolina, where the wind was north east all day, probably not strong, as the force is not mentioned. In short, by casting the eye on the chart, it will appear, by directing the attention to the north west side of the storm, that the wind had a tendency to rotate from right to left; and again, if attention be directed to the south east side of the storm, it will appear that the wind had a tendency to rotate from left to right — which precludes the idea of a general rotation the same way — and shows that there was some cause which induced the wind at the extreme north west and south east and east, to move towards a point in the storm, south of its centre. These anomalies cannot be explained fully by the facts collected, without the aid of hypothesis, and I do not permit myself to *hypothesise.* We have no barometrical observations south of Washington; yet from the immense quantity of rain and snow which fell in the north west corner of North Carolina, it is not improbable that a much greater quantity fell in the southern part of the storm than in the northern.

Besides, as the barometer fell much more at Washington city than at Philadelphia and places further north, it may be that it fell still more further south and west. But I forbear to conjecture.

RATIONALE.

It will not be esteemed by the reader impertinent in me to offer my views as to the modus operandi of nature in producing the various phenomena accompanying the storm of the 17th March, as detailed in the "Report" of the Meteorological Committee, and summed up in the preceding statement of the facts.

The upward motion of the air in the region of a storm, may take its commencement either from a higher temperature, or a higher dew point.

As the air rises in the inner portions of the storm, it is reduced in temperature by diminished pressure, a little more than 1° for every hundred yards of its ascent, as I have ascertained by experiment; and when it has ascended as many hundred yards as the temperature of the air is above the dew point, the vapor will begin to condense into cloud, and give out its caloric of elasticity — this caloric of elasticity is received by the air in contact with the condensing vapor, and prevents the air in its further ascent from cooling as fast it would, if there was no vapor in the air to condense; and, I find, both by calculation and experiment, that in ordinary states of the dew point, it cools only half as much in its ascent above the base or lower part of the cloud, as it would do if no latent caloric were given out; and that in all states of the dew point, the air in the cloud at the moment of its formation, is expanded about six thousand six hundred cubic feet for every cubic foot of water generated by the condensed vapor, after making allowances for the condensation of the vapor itself.

The great expansion of the air in the cloud, will cause a rapid ascent and out-spreading above, which will cause the barometer to fall under the cloud, and if there was no current above, it would spread out on all sides equally in an *annulus*, and cause the barometer to rise all round the storm, as much on one side as another. But as there is known to be an upper current always, or almost always, moving in this latitude towards the north east or N. N. E., this current will cause the out-spreading of the air to be chiefly in that direction, and consequently the barometer will rise chiefly on that side of the storm, at the very time it is falling within the storm, as it actually did in Connecticut and Rhode Island, while it was falling in Annapolis and Washington city. Now if it should be found that the rise extended to Albany and Utica, the explanation of that remarkable phenomenon mentioned before, of the wind's blowing outwards in all directions from that region, it will be acknowledged that this is the true explanation of it.[1]

If it should be found that the barometer did not rise at these places, some other facts may yet be discovered to explain the anomaly.

On the very great irregularities presented at Meadville and Lexington, I have nothing entirely satisfactory to say. In a storm of such great magnitude, many irregularities might be expected.

I have been told by those who have witnessed the phenomenon from very lofty mountains, when it is raining in the valley below them, that the top of the cloud, which they could see spread out before them, did not exhibit a level plain, but many pyramidal elevations were to be seen rising considerably above the ordinary level. Now this

[1] Since writing this article, Matthew Webster, Esq., has given me the following Journal, from which it appears that the barometer actually rose on the 17th, as the theory seemed to indicate it should at Albany.

MARCH, 1838.

14—6 P. M. Bar.	30.05 Ther.	43½	43	S.	light, clear,
15—9 A. M.	29.98	40	45½	N. E.	" cloudy,
6 P. M.	29.895	46	43½	N. W.	" cloudy, ice in front of city moved.
16—9 A. M.	29.975	40½	43	N.	light, clear, river clear.
6 P. M.	30.040	43	39¼	N.	" cloudy, snow at night.
17—9 A. M.	30.12	37½	37½	N.	" cloudy.
18—9 A. M.	29.95	36½	34	N.	" snow com. 8 A. M.
6 P. M.	29.865	36	32	N.	" snow.
19—9 A. M.	29.700	35½	37	N.	" cloudy.
6 P. M.	29.55	41	40	N. W.	" clear.
20—9 A. M.	29.675	38	42¾	W.	" cloudy.

seemed to indicate a more violent action under those elevations than in the other parts — and if we conceive the action very great as it is in all summer hail storms, in which the drops of water are carried up to a great height and frozen — the snow might not be permitted to fall down where it was generated, but be carried off to some distance from where it was taken up, and thrown down in such quantity as to cause, by its weight and cooling effect together, the wind to blow outwards in all directions from its place of descent. Many such places might be formed in a storm, five hundred miles in diameter, and, of course, many irregularities be produced, similar to the one in question. These particular, violent, upmoving currents, and down falls of snow by their side, would be very likely to occur in the neighborhoods of hills and mountains. For the air, rushing in towards the centre of the general storm, on coming to a hill, will glance up it, and, having acquired an upward motion, will be inclined to continue it, and thus produce the effect in question. And if the hill is very lofty, as the Himalayas, the snow will be thrown down on the windward side; but if it is of moderate elevation, the snow may be thrown down on the leeward side. In the former case, the wind may be forced down the side of the mountain on the windward side at the surface of the ground, whilst a few hundred yards high, it may be blowing up the mountain over that at the surface of the earth blowing downwards.

It is also known that a violent summer shower often causes the wind to blow outwards in all directions from the falling shower, when a few minutes before, it had been blowing the contrary way, towards the forming cloud, and the wind at some considerable distance from the falling shower, still continues to blow towards the rain, glancing up over the outmoving current. In this way, new columnar clouds are seen to form rapidly to the windward of the rain cloud. If, during the progress of a great storm, it should sometimes snow or rain violently, and at other times stop, with increase or diminution of wind, it might be safely inferred that some such action as that just described is going on. In that case, too, a person below the clouds may sometimes distinguish these cones, which raise their tops above the general level of the cloud above, for their bases will be much blacker than the surrounding clouds. After all, we must wait for future and more abundant facts to explain these irregularities.

As to the direction in which the storm moved, and its velocity, we have but little to say, because it is entirely beyond the power of the theory to predict in what direction storms in general will move. It is highly probable, indeed, that very narrow storms of great violence, such as tornadoes, in which the drops of rain are not permitted to fall back through the ascending current, but are thrown outwards, at a great height, frozen into hail, will all be found to move in the direction of the upper current — that is, westwardly, or towards the west in the torrid zone, northwardly from the tropic of Cancer to latitude thirty, and north easterly or eastwardly in the latitude of Philadelphia.

For the tornado cloud, forming only when the dew point is very high, that is when the steam power in the air is very great, (for all storms are produced by steam power,) it will rise very high, and of course a large portion of its upper part, being in the upper current of air, it will be pressed by that current in its own direction. Therefore the tornado, as long as it lasts, must move in that direction. But in case the rain falls down through the base of the cloud, as in ordinary showers, the descent of the rain produces a disturbing force below, and the accumulation of drops of rain in the cloud prevents the cloud from rising so high into the upper current as in the tornado cloud, and besides the air, on the northern border of the storm being colder and of a lower dew point, will, by its greater weight, have a tendency to press the storm towards the south, and these forces not being exactly known in quantity, we must wait till a patient induction from accumulated facts shall solve this most interesting problem.

Another highly interesting question can only be answered by very numerous observations with the barometer. How far is the snow and rain carried by the out-moving current above, beyond the up-moving current in the middle of the storm?

This distance will no doubt vary with the violence of the storm. In a case of great violence, if the storm is quite narrow, the upward current in the middle may be so great that the snow or rain may not be permitted to fall in the centre of the up-moving current at all — but be compelled to pass outward above in all directions, and fall down in an annulus, where the barometer may even be above the mean, and rise during the fall. Something of this kind seems to have taken place in the present storm, in the northern part of Pennsylvania, extending from Sunbury and Silver Lake, even as far down into the centre of the state as Bellefonte. For, at the two former places the barometer did not fall at all, and at the latter its fall was hardly sensible. At these places, therefore, it is highly probable, there was no upward current of air, and consequently the snow which fell there, must have been generated at a distance. How far this fall of snow may have been, not only the cause of the irregularities at Silver Lake and Meadville, which were mentioned before, and of the very gentle winds about this region, but also of the general tendency of the winds to move on the east and west side of the storm towards a point south of the centre, it is not necessary for me now to determine; at present it is sufficient to have pointed out this source of irregularity, and leave it to future investigation to determine its exact amount.

Another highly important question is suggested here—how far beyond the boundary of the falling rain or snow in these wide extended storms, does the wind blow inwards towards the storm? And how long before the beginning of the rain or snow, does the wind change in front of the storm? It seems probable that the time and distance to which the in-blowing extends, will be directly as the magnitude of the storm, and the facts ascertained are favorable to this deduction. At Philadelphia, the wind changed round by N. to N. E. exactly twenty-four hours before the rain commenced. At Middletown, Conn., the wind changed about twenty-four hours before the storm came on. At New Bedford and Northborough, Mass., and at Providence, R. I., the wind changed round from thirty to forty hours before the commencement of the snow. But in no case did it become so violent as to attract much attention, until within a few hours of the commencement of the rain or snow. I say rain or snow, for in the northern parts of this storm, it was snow, and in the southern parts, rain and hail. And it is worthy of particular remark, that during the whole progress of this storm, as far as our observations reach, the wind was most violent on the north east of the storm, and least violent on the south west of it. This is what we ought to expect from the rise of the barometer on the north east side of the storm, as mentioned before. I have in my possession proofs that this is the case in *some* other wide extended storms; further investigation must decide whether this is the case in *all* such storms.

Even in those very narrow storms called *Spouts*, I have been informed, by eye witnesses, that some have the trees thrown down contrary to the motion of the spout along the surface of the earth. Such has not been the fact in those spouts which I have visited. In all I found the tops of the trees on the south side of the spout lying towards the north east, on the north side towards the south east, and if occasionally trees were lying across, those underneath were thrown inwards and backwards, and those on top were thrown inwards and forwards. The Brunswick spout of the 19th of June, 1835, affords a well known example of this, an account of which is given by A. D. Bache, President of the Girard College, in the transactions of the American Philosophical Society, and also by Professor W. R. Johnston, in the Transactions of the Philadelphia Academy of Natural Sciences. (See Sect. VII.)

Another remarkable fact will not escape the observation of the reader who examines with care the report of this storm. The wind on the 16th, before very much rain and snow had fallen, was every where feeble and irregular, and especially so in the New England States; but on the 17th, when much rain and snow had already fallen, the wind became strong, and the irregularities nearly ceased. So on the western border of the storm, at Wilmington, for instance, the wind was much stronger on the 17th than it had been on the 16th.

The several links of our chain of argument may now be exhibited in juxtaposition.

1. The air did blow inwards towards a region not far from the southern border of the storm.

2. The air did therefore ascend over that region.

3. It cooled a little more than one degree of Fahrenheit for every hundred yards of its ascent, as is known by experiment.

4. When it ascended as many hundred yards as the temperature of the air was above the dew point, the vapor in the air would begin to condense into cloud.

5. When the vapor began to condense, its caloric of elasticity would be given out to the air in contact with the condensing vapor.

6. This caloric of elasticity would change the law of cooling, in ordinary states of the dew point, from one degree for a hundred yards of the ascent to one half a degree, so that the air *in* the cloud, was one half a degree warmer

than the air on the *outside* of the cloud, for every hundred yards above its basis.

7. The specific gravity of the cloud will thus be less than that of the air at the same height, a quantity which can be calculated if the dew point and the height of the cloud are given.

8. The air in the cloud will therefore move upwards in the middle, and outwards above, and inwards below, with a depression of the barometer under the cloud, and a rise all round the cloud, produced by the outspreading of the air above.

9. If the depression of the barometer is given, the velocity of the upward motion will be known, at least in the case of tornadoes or spouts.

10. If the velocity of upward motion is known, the quantity of vapor condensed in a given time is known.

11. The commencement of this upward motion may depend either on a higher temperature, or a higher dew point than in surrounding regions.

12. The barometer would probably rise more on the north east side of the storm than on any other side, on account of the general motion of the upper portion of the atmosphere, being towards the north east in this latitude.

P. S. A journal of the weather for the month of March, 1838, was kept at St. Mary's College, Frederick Co., (Md.) by Professor Elder, and it appears by it that the wind was very violent all day on the 17th, from north west to north, with but little depression of the barometer, 1-10th inch from the 16th.

The wind on the 18th was still very strong N. N. W., and it did not entirely cease snowing till about two o'clock. Mr. Elder thinks if it had been all snow and no rain, it would have been three feet deep.

I have also received a letter from Professor G. W. Keely, of Waterville, Maine, from which it appears that the wind was north west on the 17th, nearly clear, some clouds in the south. The barometer rose 33 one hundredths of an inch from the 16th, and there was a little snow at two o'clock, P. M., of the 18th, and the barometer did not fall much till the 19th.

In a letter from the Hon. Henry Connor, of North Carolina, in the southern part of the state, a little west of the middle, he says — "I was not at home when the storm took place, but it was very severe, as much timber was blown down; and the wind must have been from the south, as the tops of the trees were all lying toward the north.

Arrow No. 18½ is added to the chart from Mr. Connor's letter, and if the reader will add one for Professor Elder's account, at Frederick, Md., the phenomenon of the inward motion of the wind toward the centre of the storm becomes very decided.[1]

Directions. — By the Joint Committee.

117. *Thermometer.* — The thermometer should be placed in a situation screened from the direct rays of the sun, and also as free as possible from the contact, reflection and radiation, of surrounding bodies. If a place free from radiation cannot be procured, the effect of radiation may be obviated by swinging the instrument briskly in the air, or fanning it where it hangs. The self-registering thermometer should be placed in a horizontal position out of doors, and screened from the open sky; the lowest temperature to which it sinks in the twenty-four hours should be noted. From this temperature, and the two o'clock observation, the mean is obtained.

Some time, during the warmest part of the day, the instrument should be held with the bulb uppermost, until the enamel index descends to the extremity of the liquid in the tube.

[1] The above condensed Statement of the Facts, and Rationale, were written by the author in his individual capacity, and had not the sanction of the Committee.

The Barometer — Should be hung perpendicularly, and the screw at the lower end loosened, until the mercury ceases to fall. When taking an observation, the barometer should always be slightly agitated or patted, to obviate the effects of friction. The movable index or vernier should then be set to the top of the mercury, and its height be read off to the nearest $\frac{1}{100}$ of an inch. During the passage of storms, it will be highly important to note, as near as may be, the moment of greatest depression.

Wind and Clouds. — The wind and clouds should both be noted in the direction from which they are coming: thus, if both proceed from the west, they should be marked $\frac{\text{W}}{\text{W}}$; and if the wind should be east, and the clouds from the south west, they should be marked $\frac{\text{S.W.}}{\text{E.}}$, the lower letters always denoting the wind, and the upper letters the clouds. Also the force of the wind and velocity of the clouds may be denoted by the figures, 0, 1, 2, 3, 4, 5: 0 signifying a calm, or no motion in the clouds; 1, a very gentle breeze, or a very slow motion in the clouds; and so on till 5, which signifies a very strong gale. According to the same scale, a tornado would be marked 10.

For example, should the wind be a moderate breeze from the north, and the clouds moderately fast from the W. S. W., the whole would be marked $\frac{\text{W.S.W. 2}}{\text{N. 2}}$; and should the air be nearly calm below, and the clouds very fast, all in the same direction as before, it would be noted $\frac{\text{W.S.W. 5}}{\text{N. 1}}$; but in case there should be two or three currents of clouds, the fact must be noticed among the general observations, or thus, $\frac{\text{W. 1}}{\frac{\text{S. 2}}{\text{N.W. 2}}}$: the uppermost letter denoting the upper clouds, the middle letter the lower clouds and the lowest letter the wind; the velocity of each current being expressed by numbers as above.

The Dew Point. — For the method of finding dew point, see first circular (98).

Clearness of Sky. — The clearness of the sky may be designated by the figures, 0, 1, 2, 3, 4, 5, &c.: 0 signifying entire cloudiness; 1, a very small portion of clear sky; and 10, entire clearness. To save room, the numbers expressive of clearness may registered in the same column with the barometrical observations. For example, if the barometer should be at 30.10, and the sky half clear, or 5, this should be marked, in the column headed "barometer," $\frac{30.10}{5}$.

Rain Guage. — The *rain guage* should be placed in some position near the ground, where it will receive the rain, let the wind blow from whatever direction it may. The height of this instrument, above the ordinary level of the ground, should be mentioned in the first monthly report. As soon as possible after a rain, the water collected in the receiver should be measured in the glass tube, which is graduated so as to read to thousandths of an inch of rain falling into the guage. In cold weather, the receiver may be surrounded with straw, to prevent the water from freezing immediately.

Where the precipitation consists of snow, it is usual to estimate one foot in depth as equal to one inch of water.

General Observations. — Under this head should be noted all remarkabe phenomena which cannot be inserted in the regular columns, such as any sudden change of wind or temperature; times of clouding, with the varieties of clouds prevailing through the day; halos, auroras, fogs, thunder storms, near or remote, silent lightning, with its direction and elevation above the horizon, &c.

Hints to Observers on Meteorology.

118. The legislature of the State of Pennsylvania, at their last session, appropriated four thousand dollars for the advancement of meteorology, and out of this sum, which has been placed at the disposal of the Joint Committee on Meteorology of the American Philosophical Society and Franklin Institute, a barometer, two common thermometers,

a self-registering thermometer, and a rain-guage, have been purchased for each county in the State, which are to be placed in the hands of some skilful observer, who shall volunteer to keep a journal of the weather according to a common form prescribed by the committee.

My principal object in writing these hints is, not merely to assist our correspondents in the State of Pennsylvania, but to induce many others to keep journals of the weather according to their means, and thus contribute their mite towards enabling the committee *to find out the course that storms take over the surface of the earth in all the different seasons of the year*, and, consequently, their velocity and *shape*, with the force and direction of the wind in their borders, both at the surface of the earth, and in the region of the clouds. Now, as these primary and highly important observations may be made without instruments, I beg that no gentleman to whom this circular is sent, may be deterred from keeping a journal of the weather from an idea that his observations can be of but little avail.

If he faithfully records all the phenomena of the weather, particularly of the winds, clouds, and rains, it will be of incalculable advantage in the further investigation of storms.

119. To those who have a thermometer, it will be interesting to know that the height of the base of those clouds (which generally form in a summer day, when the heavens are not overspread with clouds, and disappear in the night; and which, when large and well formed, have broad, flat, dark bases, with tops as white as snow, and rising sometimes to a great height at the top, while the base continues on the same level, assuming the appearance of a cone) can be ascertained in the two following ways:

1st. Find the *dew point* in the manner directed by the committee in their printed instructions (98), and the difference between this and the temperature of the air at that time is called the *complement of the dew point.*

This complement being multiplied by 100 will give the height of the base of the clouds in question in yards, nearly.

2d. Put a thin, white, wet rag round the bulb and lower end of the thermometer, and swing it briskly in the air, and ascertain the greatest distance or number of degrees it will sink below the temperature of the air; this number is called the complement of the wet bulb: now, 10300 times this complement being divided by the wet-bulb temperature, will give the height of the base of the same clouds in yards, nearly.[1]

When the difference of the temperature of the air and that of the dew point amounts to 20° or 21°, or if the surface of the ground is colder than the air, it is believed these clouds hardly appear, or, if they do appear, are very

[1] When the temperature of the air is near the freezing point, great care must be taken that the bulb of the thermometer be covered either with a film of ice or snow entirely frozen, or wet rag entirely unfrozen; for if the water of the wet rag is freezing, or the film of ice thawing, the true wet bulb temperature cannot be obtained. When the temperature of the air is a little above the freezing point, and the dew point greatly below it, the wet bulb may sometimes be obtained without freezing as low as 27°, or 5° below the freezing point; and, in such cases, I have found that the wet bulb was exactly at the same temperature as the bulb surrounded with a film of ice, allowance being made for the difference of the thermometers. From this experiment it appears that about one seventh less evaporation goes on from ice than from water at the same temperature; for the caloric of fluidity of water is about one seventh of the caloric of elasticity of steam.

Those of our correspondents who live in very cold localities, have it in their power to perform a very interesting experiment, which I recommend to their special attention. From it the lowest degree at which vapor can exist may be nearly determined.

When the temperature is very low, examine how near two thermometers agree; dip one of them in water, and draw it out immediately; it will be surrounded with a film of ice; place it in the same locality, and note whether it sinks lower than the other: if not, no vapor rises from the ice, and, therefore, if the air is clear at the time, vapor does not exist in the atmosphere at that temperature. All experiments with the thermometer, at such low temperatures particularly, require great care — the radiation from the body, and the influence of the breath, should be guarded against as much as possible.

short. It may be added that this is the cloud which forms the thunder shower in summer, and is known in the books by the name of *cumulus*. When this cloud rises with its top to a considerable height, it frequently enables the observer to ascertain the direction of the upper current of air, for the top of the cloud will lean in the direction of that current.

120. Our correspondents will be richly rewarded by observing this cloud with great care. It generally begins in clear days to form (when the complement of the dew point is not great) pretty early in the morning, and as generally disappears in the evening; sometimes it appears thin and ragged in its borders, and sometimes its borders are well defined, and its top and sides as white and apparently as dense as snow. The tops of very lofty ones generally lean towards the east or north of east at Philadelphia, because this is the direction in which the upper current moves; and, from the theory of the trade winds, it is presumed that in the latitude of New Orleans the tops generally lean towards the north, and in lower latitudes towards the north west. When the wind is from the south west they are more likely at Philadelphia to rise higher and lean less.

121. Sometimes they are observed to swell out above, as if they were blown with a large bellows below; and occasionally, in such times, a thin film of cloud is seen to form in the clear sky above them, at a short distance, which gradually, by the upward motion of the cloud below, is overtaken by that cloud, and then seems to spread over it, as a thin veil over a bank of snow. This thin cloud is formed by the upward motion of the other lifting up the air above it, and cooling it by expansion, and is denominated a *cap*. When these caps form, it generally rains. Is there any thing in the appearance of these clouds while forming which will indicate whether they will rain or not with absolute certainty? When the top of this cloud rises to a very great perpendicular height, the barometer un-

derneath the base sinks proportionally, and the upward motion of the air in the middle of the cloud is sometimes so great as to carry up the drops of rain above the region of perpetual congelation, and throw them out on both sides of the cloud frozen into hail.[1] Does hail of great size ever come down through the base of the cloud? And when a summer cloud begins to rain down through its base, does it always stop the upward current in the middle of the cloud, and finally invert it, causing the air to move downward in the middle of the rain, and outwards at the surface of the earth, contrary to the motion it had inwards while the cloud was forming? Or does the air sometimes, even after the commencement of the rain, continue to run in under the base of the cloud round the borders of the rain, glancing up over air pressed downwards in the centre, and outwards at the surface of the earth, by the weight of the rain and its cooling effect on the air through which it passes? If the latter is sometimes the case, in what direction does the rain then move along the surface of the earth? If the former is sometimes or always the case, then, as the individual cloud will of course cease to rain in a short time, how is the rain continued? If it is by new clouds springing up in its borders, do these new clouds generally

[1] The velocity of this upward motion may be calculated by an observer, over whom the middle of the cloud passes, by the following formula: Note the height of the barometer at the moment of the calm which precedes the storm, and also at the moment of the calm in the middle of the storm; take the difference in inches; eight times the square root of 900 times this difference will be the velocity in feet per second of the upward motion of the air in the centre of the storm, nearly. For example: if the barometer should sink one inch in the centre of the storm, the velocity upwards in that centre would be $8 \times \sqrt{900 \times 1} = 240$ feet per second. This formula is founded on the fact that nine hundred feet of air in height weighs about as much as an inch of mercury, and then the formula for spouting fluids applies. No allowance is to be made for resistance, as the up-moving column passes through the surrounding air; for it is known by experiment, that water, under a given head of pressure, flows through an aperture with the same velocity as into air, its velocity depending entirely on the head of pressure.

form on the south or south west side of the parent cloud, where the dew point is generally highest in this latitude? and, in this case, does the rain travel in the same direction as in the other?

If it should be found that some rains travel towards the south or south west, in consequence of the cold air, through which rain has passed, pressing in that direction, and the warm air, with a high dew point, coming from the south-west, glancing up over it, as over a mountain; how are these rains to be distinguished from the others? Does the rain vary in its direction and velocity along the surface of the earth with the different seasons of the year? and is there any general law on this subject?

It would be highly useful to note the time when these columnar clouds begin to form in the morning, and when they disappear in the evening; and let those who live near a mountain test the rule given above for finding the height of the base of these clouds, by noticing how the complement of the dew point increases in the morning, as the clouds rise higher and higher up the side of the mountain.

122. On this point the following plan may be adopted; Let the observer previously take his barometer with him up the side of the mountain, and mark how much it falls at particular places, which can be distinguished from the valley below, where the observer lives; and then let him observe whether the complement of the dew point is four degrees for every inch of mercury that the barometer would fall on being elevated to the base of the cloud. By a great number of such observations, carefully made, the rule given above may be corrected if it should be found not exactly accurate.

123. It will also be very important to note the direction of a very lofty cloud (which seems to be formed out of the top of a rain cloud,) very thin and fibrous, called in the

books *cirrus;* but which is very generally known by the name of *haze.*

This cloud, at Philadelphia, nearly always comes from some western or south western point; and it is believed, both from theory and numerous observations, that, when a rain is going on at the north west, it becomes more western, or even north of west. The cause of this is manifestly the outspreading of the cloud, which protrudes the air outwards in an annulus all round the region of the cloud, at the height of the cloud itself. This protrusion of the cloud is sometimes manifest from the shape of the thunder storm cloud, especially the hail cloud, spreading out at the top like a mushroom, or hour-glass; and, in such cases, the precipitations of hail and rain are seen falling from the outspread annulus into the clear air below. The height of this annulus is great, but not exactly known.

These points, therefore, require further observation and confirmation.

When any sudden change in the wind takes place, let the time and direction be carefully noted. And when a tornado occurs, run to the barometer and mark the lowest point to which it sinks, and the time it takes to rise a given quantity after the passage of the tornado. Also, if any remarkable tornadoes happen, or have happened, in your neighborhood, visit the ground where they have passed, and see in what manner the trees have been thrown down. In the Brunswick tornado, in 1835, June 19, all the trees were thrown with their tops inwards, and generally forwards; if some were occasionally thrown backwards, they were invariably found to be underneath those which were thrown forwards, when any were lying across, and those trees underneath, it is believed, were the most easily thrown down. Let this point be examined as to other tornadoes or spouts. In the Brunswick spout, a vein of hail fell, not in the path of the spout, which was not more than three hundred or four hundred yards wide, but at some distance from it, in a zone on the north side, along with the shingles which were taken up from Brunswick, extending more than twenty miles beyond Brunswick, and fifteen miles north east of Amboy, where the spout disappeared at the surface of the earth.

Does the hail or rain in spouts always fall on the north side, or does it sometimes fall on both sides of the path of the spout?

If there is any thing remarkable in your locality as to mountains, please to mention it in your first journal.

During the progress of a storm, take frequent observations, especially noting the time of the heaviest fall of rain, hail, or snow, the maximum and minimum of the barometer; any change of wind in strength or direction, and so of the clouds.

124. The barometer generally stands lowest near the middle or end of storms, and not unfrequently, in the winter months, suddenly rises about two days before the commencement of a great storm. This is a highly interesting point for further examination. Is this rise caused by the outpouring of the air above a storm raging at that time in the south west, carried especially to the north east by the upper current of air?

At the termination of our great north east winter storms, which are known to move from the westward to eastward, with a velocity of about twenty-five or thirty miles an hour, the wind frequently changes round, sometimes one way and sometimes the other, and settles in the north-west; while the clouds above continue to come with increased velocity from the south west. Let this point be noted; and if there is any general law on this or any other subject of meteorology, already known in your locality, mention it in your first journal. It is believed that during the whole progress of these north east storms at Philadelphia, the uppermost clouds are coming from the south west. Indeed, these north east storms are frequently announced, not only by a sudden rise of the barometer, as just mentioned, but by a hazy cloud rising in the south west opposite to a north east wind.

125. When a summer storm passes in sight, note the phenomena. Not unfrequently the barometer rises in the borders of the storm, and, during the rain or hail, the wind blows outwards from the centre of the shower. It is very desirable to know to what distance this outward wind and rise of the barometer reach, and what effect it has in generating new clouds, by the warm moist air blowing up over it. The dew point frequently falls by this outspreading of the air below, reaching an observer at some distance from a rain, and thus becomes a forerunner of an approaching shower, generated in the manner indicated above.

If a mountain were suddenly elevated by volcanic agency across our country from north west to south east, it would become the immediate cause of rain, by the air rising up over it as it blows from the south west. Every thunder shower produces a mass of cold heavy air, through which the drops of rain or hail have passed, tending to produce a new shower on the windward side of this cold mass, just as a mountain would do. To investigate all the phenomena of this summer shower, forms no inconsiderable part of our present object. I hope next year, if Congress should this winter lend their powerful aid to this important undertaking, to be able to investigate our great north east winter storms in like manner; for our wide extended territory is peculiarly suited to this investigation. At present, we neither know the size nor the shape of these storms; though the direction in which they move, and their velocity, are better known than those of any other storms, with the exception of the summer tornadoes, which nearly all move from the south west or W. S. W. in this latitude. Indeed, it seems probable, that these tornadoes can only occur when the wind is from the south west; for, if the wind is in any other direction, a cloud reaching from the ground to so great a height as a tornado cloud, even if it could be formed, would probably be cut in two by having its upper end pressed over to the north east, and its lower end driven in the direction of the wind at the surface of the earth; and thus not even a thunder storm could be formed, much less a tornado, which requires a cloud of immense perpendicular height and depth. This, however, being a deduction of theory, requires further confirmation by observation.

126. Even in cases where the wind below moves towards the north east, but with a slower motion than the uppermost current, it seems probable that a cloud, which is formed by an up-moving column of air, may sometimes be pressed on towards the north east by the upper air faster than the up-moving column can move in that direction, and thus its connection with the up-moving column be cut off. This cloud will then cease to enlarge, and, if the column of heated air under the cloud should remain unbroken, another will begin to form to the south west of it, and so of a third and a fourth; and, in this case, should the range of clouds be to the north of the observer, the western clouds, though smaller than the eastern, would appear in perspective nearer than the eastern, and conversely in the southern horizon; for there the western ones would be nearly concealed by the eastern ones.

These theoretical views are thrown out, not to bias public opinion, but to aid in making observations.

127. It is of considerable interest to know how high the tops of these thunder clouds rise, and to those who are curious on this point, we would recommend the following plan: — when a thunder storm, or violent hail or rain, passes over late in the afternoon, and leaves the western sky perfectly clear, mark the time by your watch when the

sun sinks below the horizon, and also the time when his last rays fall on the top of the cloud; at the same moment take the angular height of the top of the cloud with your sextant, and also its direction; then you will have data for finding the height of the cloud by trigonometry: or the distance of the cloud may be computed by observing the interval of time between a flash of lightning emanating from it, and the succeeding thunder. This interval in seconds multiplied by 1142, will give the distance of the cloud in feet. The distance and angular elevation being known, the height can be ascertained by a simple trigonometrical calculation. One was so calculated by the writer of this circular, and found to be about ten miles high. (81.) Further observations on this point are desirable.[1]

128. Sir John Herschel has recommended that hourly observations, for thirty-seven successive hours, be made four times a year, beginning at six, A. M., on the 21st of March, the 21st of June, the 21st of September, and the 21st of December. Many observers, in various parts of the world, have commenced these observations, and some important facts have already been discovered by them. We hope that very many of our correspondents will follow the example; and to those who do, we recommend, according to a suggestion of Mr. Redfield, that some account of the weather, before and after this period, be given — especially if a storm occurs, that all the phenomena of the storm may be known.

At the time of all storms, it will be highly important to make the observations as numerous as convenient, always noting the exact time of taking the observation, even to a minute. In this way, so many almost simultaneous observations will be made on the same storm, that even a summer's thunder shower cannot spring up in our borders with-

[1] As the dew point in this country in the summer, is much higher than it is in Great Britain, it ought to be expected that clouds would shoot their tops much higher here than there; because the steam power is greater.

out being under the eye of several observers; and thus it is hoped the exact direction in which all the storms move, and their velocity along the surface of the earth, will, in a few years, be found out.

When no remarkable changes are going on in the atmosphere, three observations will be sufficient in the day, at seven, A. M., at two, P. M., and at nine, P. M., or as near those hours as possible, always noting the hour and minute when the observation is taken, in case a storm is progressing.

Much curious information, and valuable to the farmer, would be obtained, if our correspondents would, in clear calm nights, observe the difference of temperature of the air at the bottom of the hollows, and on the slopes of surrounding hills and tops of knolls. They will find, at a certain height, that the temperature remains nearly constant, while, at the bottom of the valley, the change is very great; and from this investigation they will learn at what height it will be best to plant their orchards, to prevent their fruit from being killed by frost. Any information which our correspondents may give us on this subject, or any other — such as frosts, dews, fogs, clouds on sides of mountains, and their height in connection with the dew point, will be thankfully received, and be added to our common stock of knowledge.

Especially if a land spout or tornado passes near you to the north or south, carefully ascertain the angular height of the cloudy pillar, where it joins the black cloud above, by placing yourself in such a position as to have some fixed object between your eye and the top of the pillar or spout, and afterwards the angular height can be ascertained by the quadrant, and so the height of the spout be known by trigonometry; for the distance of the observer from the path of the spout can afterwards be measured. Do not fail to take the dew point and temperature of the air at the same time; and if, at any time, you should be able to see the top of the cloud above the cloudy pillar, endeavor to find out its height in the same manner, and describe its form, and all the phenomena attending it, as near as possible.

129. For the sake of our correspondents who may not have access to tables, we insert a table of dew points, in which the column to the left is the dew point temperature, the middle column the corresponding elastic force of the vapor in the air in inches of mercury, and the right hand column is the weight of the vapor proportional to the air containing it when the mercury stands in the barometer at thirty inches, the weight of the air being unity.

Temperature of dew point.	Elastic force.	Weight of vapor.	Temperature of dew point.	Elastic force.	Weight of vapor.
32°	0.200	1-240th	57°	0.474	1-101st
33	207	232d	58	490	97th
34	214	224th	59	507	94th
35	221	217th	60	524	91st
36	229	209th	61	542	88th
37	237	202d	62	560	85th
38	245	195th	63	578	83d
39	254	190th	64	597	80th
40	263	188th	65	616	77th
41	273	175th	66	636	75th
42	283	169th	67	655	73d
43	294	163d	68	676	71st
44	305	157th	69	698	68th
45	316	152d	70	721	66th
46	328	146th	71	745	64th
47	339	141st	72	775	62d
48	351	136th	73	796	60th
49	363	132d	74	823	58th
50	375	128th	75	854	56th
51	388	124th	76	880	54th
52	401	120th	77	910	52d
53	415	115th	78	940	51st
54	429	111th	79	971	49th
55	443	108th	80	1.000	48th
56	458	104th			

JAMES P. ESPY, *Meteorologist.*

Philadelphia, July 7, 1837.

From an Essay on Meteorological Observations, by J. N. Nicollet, Esq., written in compliance with a wish expressed to him by the Honorable J. R. Poinsett, Secretary of the Department of War, I quote a few interesting paragraphs, as being peculiarly appropriate here.

THE FORMATION OF CLOUDS.

130. There is a certain kind of cloud which forms only in the day, when the heavens are not overspread with other clouds, and when the dew point is not too low, which, when well formed, generally appears with a broad dark base, and narrow top, something in the form of a cone, with sides as white as snow. There is no cloud ever seen below the base of this cloud, but it frequently rises with its top above the highest clouds, which it pierces with its snow-white top. As it passes through the uppermost or feathery cloud, it seems to lift the thin cloud before it, and condense it into a semi-transparent veil, which at first appears at some distance above the top of the columnar cloud; but finally as the columnar one moves upwards, its well defined top reaches the thin veil and penetrates it. Very soon afterwards by the upward motion of the columnar, the veil coalesces with the columnar cloud, and can no longer be distinguished from it. The same phenomena frequently take place, when no feathery clouds are to be seen in the higher strata of air. When the top of the columnar cloud reaches a great elevation, it is seen to form above it, at a short distance, a similar veil or cap, which it gradually overtakes and coalesces with, as before mentioned. The bases of these clouds are probably all on the same horizontal level; and if the theory which has been lately advanced in the Journal of the Franklin Institute is correct, the height of these bases, is as many hundred yards as the temperature of the air is above the dew point, at the moment of observation, in degrees of Fahrenheit.

We invite the special attention of the meteorologist to be directed to this cloud. Let him watch it from the moment of its beginning to form in the morning, taking drawings of it through all its stages; noting the length of time from one stage to another, until it dissipates or produces rain. If it dissipates without raining let him try to ascertain the cause. Did its top rise into a current of air, moving in a different direction, and preventing it from rising perpendicularly, slicing off its top and dissipating it in air not saturated with vapor? Or did it spread out in all directions, and thus dissipate? Or did the failure depend on the dew point? Or what were the circumstances in which it differed from columnar clouds producing rain? In case of producing rain, let the top of the cloud be particularly noted. Did it change its appearance about the time, or a little before the rain is seen to descend from its base? And in case the cloud becomes very lofty, does the base of the cloud sometimes sink to a lower level, and appear convex below? And is an extension of this appearance the water spout? Does the cloud also swell out sometimes above, so as to form a shape something like an hour-glass, or double cone, with the apices together? What kind of cloud does this columnar or hour-glass rain cloud form after the rain is over, and how does it differ from the cloud which dissipates without raining? Does it become the feathery cloud, sinking a little at the top and rising at the base, and spreading out in the direction of the upper current? What is the direction of the upper current at the equator? Is it towards the west? If so, do storms travel in that direction and with what velocity? Near the equator, on the north side, do the storms recede a little from the equator as they travel westwardly, and so on the south side of the equator? Or is there any general law on this point?

During the rapid formation of the columnar cloud, is the wind affected? If the theory above alluded to is correct, it should blow in all directions towards the forming cloud, and upwards in the region of the cloud itself. Is there such a thing as a white squall, without any cloud formed, or about to be formed over the region of the squall?

In case of a great storm or hurricane does the wind near the equator always set in from some western point; and do tornadoes always travel in the direction of the stratum of air which the tops of columnar clouds penetrate? Or is there any law on this point? Do columnar clouds more frequently form over islands than in the open sea? And do they only form in the day when the heavens are not overcast with others, and do they disappear in the night as they do on land? Are columnar clouds formed every day not overcast? If not, what is the cause? Is it because the dew point is too low when compared with the temperature of the air? What is the greatest depression of the dew point below the temperature of the air when columnar clouds form?

How soon do they begin to form after sunrise, and when do they cease to form in the afternoon? And when do they disappear in the evening? Or is there any law on this point?

Mr. Redfield, of New York, has shown that the storms which visit the West Indies, travel north westwardly while in the torrid zone. Does the wind in these storms, which sets in from the north west, change round on the north east side by the north, and on the south west side by the west, in such a manner as to show, that the wind blows towards the centre of the storm? Or what is the general law on this point? Are these storms always attended with electrical phenomena; and is there any thing peculiar in the appearance of the lightning? When an observation is made on land, note whether the lightning descends vertically, as has been asserted, and rolls over the ground like melted metal. Inquire, when tornadoes occur, whether they sometimes lift up large trees, and set them down in a different place, on the broad base of their roots, without overturning them; whether they lift off the roofs of houses, and prostrate the walls outwards, as if by explosion, and tear up the floors of others and leave the walls standing? Are they ever attended with hail? Do great storms remain for some time stationary on reaching an island, and what evidence is there of a lull or calm in the centre of a storm? Has the barometer ever been observed at the moment of this lull, and what is the greatest depression recorded by a credible witness. Does the rain cease at the moment of the lull of the wind, and are the clouds seen at the same time to move on all sides towards the zenith?

In the case of violent storms in the torrid zone, do they always set in from some western point, and terminate with the wind from some eastern point? If they set in from a point far north of west, does the wind veer round by the north, and if from a point far south of west, does the wind veer round by the south? If this question should be answered in the affirmative, the discovery will be of immense advantage to navigation, for it will afford an indubitable proof that the wind blows towards the storm; and the knowledge of this fact will enable the mariner to avoid the storm, by sailing in a direction from the point to which the storm is advancing. Suppose, for example, that it has been discovered, that near the equator the storms travel towards the west, and that the wind, in great storms, blows towards the centre of the storm, and a violent gale sets in from the north west, it is manifest, if the mariner sails towards the north east, he will soon be out of reach of the storm; whilst, on the contrary, if he should direct his course southwardly, he would penetrate the very heart of the storm, and thus be exposed to all its violence. It is then a matter of high importance to ascertain the course, which storms travel in all the different latitudes. If the uppermost current of the atmosphere gives direction to violent storms, it is highly probable, that near the equator they travel towards the west. For as the air at the equator is lighter than the air at high

latitudes, both on account of greater heat and greater moisture, it will ascend, and in ascending, it will recede to the west, in consequence of the earth's rotation. This upper current may probably be detected by the direction in which the lofty columnar clouds lean; for their tops, when they rise to a great height, will be bent over in the direction of the upper current. Besides, as the feathery or hazy cloud spoken of above is probably formed out of the tops of columnar clouds which have rained, this upper current will most likely be indicated by the hazy clouds. Let these clouds be carefully noticed and described. Is their velocity uniform or various? Does their acceleration indicate rain? Does their increase in number indicate rain? . . . . . .
The observer will be careful to distinguish between violent storms and ordinary rains; for it may be that ordinary rains are very irregular in the direction of their motion, the tops of clouds producing them not reaching into the uppermost current, which is probably nearly uniform in its direction, while the tops of clouds producing tornadoes, may all reach into the uppermost current, and thus great uniformity in the direction of their motion may be produced. Mr. Redfield has shown that there is a remarkable uniformity in the progressive motion of storms or hurricanes, which traverse the West India islands, all moving in the direction which theory would seem to give to the uppermost current as it passes off from the equator towards the poles. The greater heat and higher dew point of the inter-tropical air will cause it to be about one sixth lighter than air in the frigid zones, and of course it will stand proportionally higher and will therefore roll off towards the poles, carrying with it in some measure, the diurnal velocity, which it had at the equator; and so moving faster than the earth at the latitude which it has reached. In confirmation of this theoretical result it is known that the highest of all our clouds in the latitude of Philadelphia, come constantly from near the

west or south west; and all the tornadoes which have been observed by scientific men, travel from a little south of west in that latitude. It may be added that of eleven land spouts or tornadoes, which passed through New York, Pennsylvania, and New Jersey, every one had the trees thrown down with their tops inwards and forwards, not one tree being discovered with its top lying out at the side. Thus proving, beyond a doubt, that in land spouts the wind blows towards the centre of the spout. How is it at sea? In several great storms in the United States, of several hundred miles in diameter, which have been investigated with great care by the joint committee of the American Philosophical Society, and the Franklin Institute of the State of Pennsylvania, the wind has been discovered to blow for many days in succession towards the storm, on all sides round the storm. Is this the case at sea?

If, as is probable, opportunities be presented of observing volcanoes, let it be seen whether they ever produce rains immediately after they break out; first, in the neighborhood of the volcano, and afterwards, extending to greater distances. Are these rains ever attended with violent tornadoes, and sometimes with hail? Are the smoke and ashes carried in all directions above to a great distance, or are they carried further on one side than on another?

The fluctuations of the barometer in connection with storms, will of course be noted. Much knowledge is yet wanted to enable us to read the indications of this valuable instrument; observe whether it ever rises before the depression which always takes place in great storms, and at the moment of the calm which may probably be experienced in the middle of the storm, mark the greatest depression.

131. The four diurnal fluctuations of the barometer should also claim particular notice. Very laborious and highly interesting observations on these fluctuations have lately been made in India, which are recommended to the attention of the meteorologist.

If these fluctuations depend on the increase and diminution of elasticity of the air by heat and cold, according to a theory published in the Journal of the Franklin Institute, the morning maximum of a considerable elevation ought to be greater than on the plain below; and the afternoon minimum should not be as low as on the plain below.

Again, the night maximum should be less and the minimum greater than on the plain. These predictions have been verified by observations. If time and opportunity should be found, they might be repeated.

The theory, however, goes further: it indicates that at very great elevations there are but two fluctuations in a day — a maximum about twelve or one o'clock in the day, and a minimum about day-break. To verify or refute this inference from theory, simultaneous observations at an elevation of fourteen or fifteen thousand feet, and on the plain below, continued for a few days, will be sufficient, if the fluctuations on the plain are regular. If a cloud is produced by the cold generated by the expansion of air as it ascends, it is manifest that the base of the cloud will be low in proportion as the dew point approaches near to the temperature of the air, and high in proportion as the dew point recedes from that temperature. . . . . .

The Franklin Kite Club, at Philadelphia, have lately discovered that in those days when columnar clouds form rapidly and numerously, their kite was frequently carried upwards nearly perpendicularly by columns of ascending air, and they say in their report, that this circumstance became so familiar during the course of their experiments, that, on the approach of a columnar cloud just forming, they could predict whether it would come near enough to affect their kite; for if the cloud did not pass directly over the kite, the kite would only move sideways towards the cloud. Now these upward columns were probably formed of air heated from contact with the ground.

Is the same effect produced at sea? Is there any connection between sudden and very limited breezes at sea and the formation of columnar clouds? . . . . .

If thunder storms occur at night, endeavor should be made to find out whether they originate in the night, or whether they are continuations of storms originating in the day. If they form at night, note whether the columns ascend from middle clouds, or whether they rise from below them. Observe where the electricity first appears in them and at what stage of their advancement, and the whole phenomena as contrasted with storms or rains in the day.

Circular of the Joint Committee on Meteorology of the American Philosophical Society and Franklin Institute.

132. Sir, — It having become highly important, owing to recent investigations in atmospheric phenomena, to ascertain the phases of the great storms of rain and snow which traverse our continent, their shape and size, what direction, and with what velocity their centres move along the surface of the earth, whether they are round or oblong or irregular in shape, and move in different directions in the different seasons of the year, &c., &c., you are respectfully but earnestly solicited to procure, in your district, answers to as many of the following questions as possible, and cause them to be transmitted to William Hamilton, Esq., Actuary of the Franklin Institute, Philadelphia.

When did the storm immediately preceding the 19th of March, 1838, commence and terminate?

In what direction did the wind blow during the storm?

Was there much or little rain or snow?

Was there much or little wind?

If the observer was beyond the borders of the snow or rain, how did the wind blow as to strength and direction on the 16th, 17th, 18th and 19th of March?

The last question is of great moment, and the committee beg of those gentlemen to whom this circular may be addressed, and who live beyond the boundaries of the storm, to favor them with a reply, if it be only to communicate the single fact of their residing beyond its limits.

Should the committee receive such answers to the questions proposed above as may enable them to ascertain the chief phases of the storm, it is their intention to publish a report of the same which they will have much pleasure in transmitting to you.

ROBLEY DUNGLISON, *Chairman of the Joint Com.*

Philadelphia, March 20, 1838.

PHILADELPHIA, NOV. 10, 1838.

To the Friends of Science in the United States.

133. GENTLEMEN: Many of you, no doubt, have already learned that a committee has been appointed by the Franklin Institute for the especial purpose of advancing the science of meteorology. The success of this committee depends on their having very many journals of the weather placed at their disposal, kept at different places in these United States. The sole object which I have in view in addressing to you the following remarks, is to satisfy you that the committee are engaged in a great undertaking, and that your aid is essential to their success.

The labors of the committee, from the beginning, have been principally to investigate the *cause* of storms, and to find out the means of *predicting* their occurrence, in time to be practically useful to mankind.

Now it appears from the Third Report of the committee, (113), that the *cause* of storms has already been discovered, and that from this discovery, and the facts connected with it, the direction in which a great storm is raging at any time, may be known when it comes within a disturbing influence; and from some facts detailed in the "First Report," (92) and also in a paper by a member[1] of the committee, which was first published in Poulson's Daily Advertiser, it appears that this disturbing influence sometimes reaches several hundred miles in distance, and more than a day in time. (171).

It remains then, when a storm comes within disturbing influence, and is known to be raging in a particular direction, to endeavor to ascertain whether that storm will reach the place of observation, and in what time; or whether it will pass to the right or the left of the observer, and in what direction the wind will blow during its passage. When this shall be done, the mariner, who has the power of locomotion, will be able, on the approach of a storm, so to direct his vessel as to avoid the violence of its centre, and keep as near its borders as will suit the purposes of navigation. And the farmer, who cannot change his locality, will at least be able to prepare for its arrival.

Now the only probable means of obtaining this highly-desirable result is to find out the shape and size of great storms, and their course and velocity over the earth's surface in the different latitudes and different seasons of the year.

If there is any general law of nature embracing these phenomena, it is highly probable that it will be discovered by a careful examination of the numerous simultaneous, or nearly simultaneous observations of these phenomena, which it is hoped will soon be placed at the disposal of the committee.

That there is a general law, as it relates to the direction in which some very violent storms of moderate size, move, has been most satisfactorily demonstrated by the labors of Mr. Redfield, of New York, and confirmed by the investigations of this committee. Besides, there is very strong

[1] C. C. Walker, Esq.

evidence in my possession, not yet published, that tornadoes or land spouts, in this latitude, have nearly one uniform direction, towards E. N. E. These facts, in connexion with the known uniformity of nature, in other departments of science, render it highly probable that other storms, and even common rains and snows, are governed in their motions by some uniform laws.

The state of Pennsylvania, acting through the intelligence of her legislature, has granted to the committee the means to investigate those storms which may come within her borders. It is confidently hoped, that in a few years, from this aid alone, much light will be thrown on all those storms, of such moderate size, that, in passing through the state, their borders are within the reach of our observers.

The great interests of navigation and commerce, however, require a much more extensive system of simultaneous observations, than the one now about to be organized in this state. Many storms, and those of the most interesting and important kind, are quite too large to be embraced within the bounds of a single state, and of course, neither the shape, nor size, nor velocity of such storms, can be ascertained by observations in Pennsylvania alone, however carefully those observations may be made.

Besides, even if it should be discovered, in a few years, that the same season in different years, will exhibit storms of similar character in Pennsylvania, it would be unsafe for the mariner, in a different latitude, to infer that he would meet with precisely similar phenomena, on the occurrence of a storm at sea.

The great interests of navigation and commerce, then, seem to require, that a much wider range of observations should be established, than the territory of Pennsylvania can furnish.

The great north east winter storms which traverse our continent, will require for their complete investigation, a system of simultaneous observations, extending over the whole of the United States, including the Bermudas, and a few of the West India Islands.

Knowing the immense importance of a wider extended correspondence, the committee, from their first establishment, have endeavored, by every means in their power, to procure journals of the weather from every part of the United States. And I have myself written to more than two hundred and fifty individuals, in the different parts of the United States, requesting them at least to send an account of the beginnings and ends of rains, and the force and direction of the winds during the time of the passage of a storm, monthly, to William Hamilton, Actuary of the Franklin Institute. How far these requests will be complied with, yet remains to be seen.

To aid the reader in understanding the investigations of the committee, skeleton maps are procured, on which are traced the shape and size of all important storms, and their progress from hour to hour.

The direction, also, and force of the wind, are indicated by arrows of different lengths, so that the reader, by a glance of the eye over these Meteorological Maps, may learn all the most important phenomena attending a storm, from the time it enters, till the time it leaves the boundary of our simultaneous observations.

The magnitude of this undertaking, and the great probability that it will result in a knowledge highly useful to mankind, are calculated to stimulate all who believe in the probability of success, to use their utmost exertions to crown the work, which has been so happily begun, with complete success. Even in case of failure, we will have this to console us: We failed in a great undertaking.

J. P. Espy,

In his individual capacity.

SECTION FOURTH.

INVESTIGATION OF STORMS.

Storm of the 26*th January*, 1839.

134. A STORM of rain, and snow, and wind, of uncommon violence, occurred in the middle and northern States on the 26th of January, 1839. I have given a summary of the documents, numbered and accompanied with a chart on which the arrows are drawn, shewing the direction of the wind near the middle of the day, at which time the central line of the storm, from N. N. E. to S. S. W., reached from the eastern coast of North Carolina to Montreal, and probably much farther. How much further it extended beyond the boundaries of the observations at my command, it is in vain to conjecture. As the barometer was extremely low at Montreal, the most northern of the observations, and as the wind changed round there from south to west, it is quite probable that Montreal was south of the centre. And as the Baltimore Chronicle, of the 8th of February, says the schooner Julia Ann was lost at sea on the 26th, in the latitude of Charleston; and the New York Gazette, of February 9th, the schooner Stephen was wrecked on the 26th, in lat. 36° 50′, long. 71° 15′, it seems highly probable the storm extended south as far as the latitude of Charleston. The southern half of this storm was, therefore, probably, at least nine hundred miles long from north by east to south by west, and, at the same time, the east and west

diameter extended from Boston — where (47) it freshened into a gale about two o'clock — to the western parts of New York and Pennsylvania.

EXPLANATION OF THE WOOD CUT.

No.

1. Washington, Michigan, wind N. W. all day of the 26th, gentle.
2. Wilmington, Ohio, N. N. W. all day of the 26th, gentle.
3. Springfield, Ohio, W. all day.
4. Kenyon College, W. by N., wind light, strong at night.
5. Cannonsburg, Pa., W.
6. Meadville, Pa., N. W., very strong all day.
7. Greendale, Pa., N. W., strong P. M.
8. Rose Cottage, S. E. at 7, A. M., then N. W., very strong.
9. Smethport, N. W., very strong.
10. Batavia, N. Y., N. W., very high after first few hours.
11. Charlottsville, Va., W., strong, fair day.
12. Alexandria, D. C., N. W., violent gale.
13. St. Mary's College, N. W., violent all day.
14. Gettysburg, N. W., brisk.
15. York, Pa., N. W. all day, severe gale.
16. Lancaster, S. S. E. till 8 3-4, A. M., then N. W.
17. Reading, S. E. at 7, A. M., then N. W.
18. Carlisle, S. W. gentle, then W. N W. and N. W.
19. Pottsville, S. E. till 9, then round by W. to N. W., strong.
20. Mifflintown, N. W. and W.
21. Lewistown, S. S. E. at 7, N. W. the rest of day.
22. Bellefonte, N. E., then N., then W.

23. Northumberland, calm at 7, A. M., then N. W. strong.
24. Burlington, N. Y., S., changing to S. W., and at 4, P. M., N. W.
25. Onondaga, N. W. all day.
26. Pompey, N. W. increasing all day.
27. Montreal, S. W., fresh and heavy rain.
28. St. Lawrence, N. E. all day.
29. Bennington, Vt., S. E. till noon, then E. very strong till 8, then W. N. W.
30. Dartmouth College, S. E. all day, high wind, violent storm.
31. Charlestown, N. H., S. E. all day, very violent.
32. Keene, N. H., S. E. all day, very powerful.
33. Waterville, Me., S. E. drawing more eastwardly all day.
34. Kennebunk, Me., southerly and southeasterly.
35. Newburyport, Mass., S. at 7, at 2, S. E., violent in evening.
36. Gloucester, S. E. at night of 26th.
37. Boston, S. E., almost a tempest in evening.
38. Dedham, S. E., strong.
39. Newport, R. I., S. E. till evening, then S. W.
39½. New Haven, E. S. E., increasing to a hurricane at 5, P. M., western at 7, light wind.
40. Stroudsburg, Pa., S. E. till evening, then N. W.
41. La Fayette College, S. E. till evening, then N. W.
42. New York, S. S. E., very violent about 2, P. M.
43. Philadelphia, S. E. till 2, then calm, at 2 h. 20 min. N. W. violent.
43½. Haverford, near Philadelphia, E. till 2, P. M., then N. W.
44. Squam Beach, S. E., severe.
45. Elkton, Md., S. E. till 2, then shifted to N. W., a perfect gale.
46. Cape Island, from N. E. to E. S. E. till between 1 and 2, then N. W., violent.
47. Snow Hill, Md., E. till 12, then W., clear at 12.
48. Schooner Railway, S. E., violent gale; schooner Wolga, same.
49. Ship Forum, S S. E., perfect hurricane from 11 till 4, then it moderated, and gradually hauled westerly.
50. Hudson, Ohio, N. W. all day, clear in morning, cloudy P. M.
51. Nantucket, S. E., on 27th W., on 28th N. W.
52. Beaufort, N. C., N. W., having been S. E., with rain on the previous night.
53. Freedonia, W. all day.
54. Lewistown, W., A. M., N. W., P. M.
55. Springville, N. W. all day.
56. Monroe, W. all day.
57. Steuben, N. W. all day.
58. Rochester, S. W., A. M., N. W., P. M., great storm.
59. Ithaca, N., A. M., N. W., P. M.
60. Lowville, N. all day.
61. Franklin, N. E. all day.
62. Plattsburg, E., A. M. and P. M.
63. Johnstown, E., A. M. and P. M.
64. Rensselear, N., A. M., S., P. M.
65. Utica, S. E., A. M., W., P. M.
66. Hartwick, N., A. M. and P. M.
67. Hamilton, S., A. M., N. W., P. M.
68. Oxford, S., A. M., N. E., P. M.
69. Cortland, S., A. M., N. W., P. M.
70. Fairfield, S. E., A. M., N. W., P. M.
71. Montgomery, S. W., A. M., S. E., P. M.
72. Redhook, S., A. M., S. E., P. M.
73. Kinderhook, S., A. M., S. E., P. M.
74. Albany, S. high, and E., very high.

135. This storm seemed to originate within the territory just named, and to have acquired its great force on the 26th. It is true it began to snow a little on the 25th, to the west, as far as Michigan and Ohio; but it acquired no violence till it reached Pennsylvania and New York. After it commenced its violence, however, it certainly moved towards the east, and if it moved exactly side foremost, its direction was towards the south of east. The observations in my possession do not enable me to decide this point with certainty. It is not a little remarkable, however, that it began to rain or snow on the 25th, in the north west part of Pennsylvania, in the northern parts of New York, and even at Montreal; and at this time the wind was in all these places southerly and easterly, as a general rule. Now it may be, that, at this very time, the centre of an incipient storm was

in Upper Canada, north west of the boundary to which our observations extend. It would be highly desirable to obtain records of the weather from Upper Canada, which alone can answer this highly important question.

136. The uncertainty, however, as to the exact direction in which this great storm moved, most fortunately for the cause of science, does not apply to the course of the wind. On this point there was a most wonderful and beautiful uniformity.

The documents abundantly show, that, for many hours during the 26th, while a very great rain and snow were falling in the region between the eastern coast of the United States and the western parts of New York and Pennsylvania, the wind on the coast, from Maryland to Maine, was almost uniformly blowing from the east or south east, and at the same time, in the western parts of New York, Pennsylvania, and the middle of Virginia and Maryland, it was from some western or north western direction. Whilst these winds were thus blowing in on both sides towards a central line, the barometer was greatly below the mean in the middle space between the two winds; and the more the barometer fell, the more violently did the winds blow on each side.

In the middle, however, the winds were very irregular along the whole length of the line from north to south; in some places they were north (64, 66), and in others (69, 72) south, violent; at others (43, &c.) calm, with the barometer at or near the minimum. In one of these places of great irregularity, there fell a very uncommon quantity of rain — 6 inches, 4 inches, and 3.55 inches; at Rensselaer, Hamilton, and Oxford, in a region forty or fifty miles in extent, and towards that region round about, the winds seemed to incline. In a storm of such great length as the present one, it is quite natural to expect that there would be some places in the central line where much more rain would fall than in others, and of course this circumstance would produce just such irregularities as took place while the centre was passing the different places. Sometimes the wind would change by the north, and sometimes by the south, and sometimes there would be a calm. As to the fall of the barometer in storms, it was first suggested by Mr. Redfield, that "the centrifugal influence which necessarily attends the action of a whirlwind storm affords an obvious and natural solution of this phenomenon." In this great storm there was no centrifugal action, and therefore his solution is not applicable to the present case. Indeed, the centrifugal action cannot take place to cause a fall of the barometer in case where cloud is formed. For if there is a centrifugal action below, the air would descend in the middle, and cloud could not be formed there. For, as the air descended, it would come under greater pressure; and if it descended to the surface of the earth from a distance of six thousand yards, it would be about 90° of Fahr. hotter by compression than it was above, and then would be able to contain about eight times as much vapor as it contained at its original altitude, even if it was saturated there. Thus it appears that in this storm, at least, the barometer did not fall from any centrifugal action, for such action did not exist. Besides, the grand, and as was supposed, fatal objection to my doctrine, is refuted by the actual facts developed in this storm. It was supposed by Sir John Herschel that, if the wind blew towards a central space, the barometer would certainly rise there above the mean. But the wind in this storm did blow in with great violence to a central space, and the barometer did not rise above the mean there, but sunk lower as the wind blew harder.

It seems to me much more philosophical to assign the fall of the barometer as the cause of the wind, than to assign the wind as the cause of the fall of the barometer.

By a fall of the barometer, I mean a diminution in the superincumbent weight of the column of air over the barometer. The cause of this diminished weight has been explained before, and its amount, under given circumstances, has been calculated. If the advocates of the whirlwind doctrine admit an inward and spiral motion, then the barometer would not fall by the centrifugal action, but rise by the accumulation of air above; unless the air above is thrown outwards by a greater centrifugal action above, or in some other way. Thus the grand objection, which they bring against my theory, becomes unanswerable against theirs, unless they can show that the gyrations above are sufficient to throw the air outwards there. This, I say, must be shown; for it will not do to assume it as a hypothesis.

137. The velocity with which this storm moved from west to east cannot be ascertained with absolute accuracy, yet a near approximation may be made by the accurate observations, at New Haven, Waterville, Philadelphia and Burlington, N. Y. The centre of the storm passed over Philadelphia at forty minutes past two, P. M., over New Haven about forty minutes past eight, and over Waterville about half past four, on the morning of the 27th. This will give a velocity of motion to the central line of the storm, side foremost, of about sixteen or seventeen miles an hour.

Now the wind at the surface of the earth, where it is subjected to much friction, was blowing in towards the central line with a velocity of double or tripple of the motion of the storm itself. A little above the surface of the earth the velocity of the air inwards would be much greater on account of the friction being less. What an amazing quantity of air rushed towards the central line of this storm, carrying with it an ocean of vapor to be condensed, by the cold of diminished pressure as it ascended.

138. We can even form some rough estimate of the relative quantities which ascended on the different sides of the central line. Much more certainly ascended on the east

side than on the west. For if the storm had moved towards the east with the same velocity as the west wind, it is manifest that *none* of the wind on the western side of the central line would have ascended, and if the storm moved with half the velocity of the western wind, then only half the western wind would ascend, &c. For example, suppose the storm moved towards the east sixteen miles an hour, and the wind blew inwards on each side with a velocity of forty-eight miles an hour, then thirty-two miles an hour would ascend on the west side, and sixty-four miles an hour would ascend on the east side. It is easy to see why much less should ascend on the western or rather northwestern side than on the south-eastern; it is because of the much greater degree of cold on the north-western side of the storm. The air on the north-western side of the central line will therefore be specifically heavier both on account of greater cold and a lower dew point. It seems probable also that this heavier air will have a tendency to cause the storm to move more to the southward, than it would independent of this influence. But many more observations on the motions of storms must be made, before we can pronounce with certainty to what extent these theoretical deductions are correct.

Perhaps it may be found, that when the north west wind is excessively cold it will not ascend at all, and then the motion of the storm will be equal to the velocity of the western or northwestern wind.

139. A violent gale of this kind seems to have occurred on the morning of the 23d, a few days before. This gale commenced at Springfield, Ohio, about 10½, P. M. of 22d, reached Lancaster, Pa. at 7h. 10m., Reading about 7h., and Philadelphia about 20 minutes before 9, A. M. This gale was preceded by no south east wind, at least at Philadelphia, and Lancaster, and Springfield, but it was every where in Pennsylvania accompanied by a furious snow

storm, commencing just before the north west wind set in. The north west wind was also very violent probably about forty or fifty miles an hour, which seems to be about the velocity with which the storm moved while passing from Springfield, Ohio, to Philadelphia.

140. The central line of this storm also was not directed exactly north and south, but east of north and west of south. It passed Stroudsburg, in the N. E. corner of Pennsylvania, ten minutes before it reached Lancaster, sixty miles west of Philadelphia. It was about an hour later reaching Snow Hill, Md., than it was in reaching Stroudsburg.

141. Here was a most remarkable vein of snow several hundred miles long from N. by E. to S. by W. and only a few miles wide, moving side foremost, and snowing only a very short time at any one place, half an hour at Philadelphia and Stroudsburg, and still less at Snow Hill and Lancaster.

This vein of snow was preceded by a fall of the barometer, and succeeded by a very sudden rise, of about half an inch in a few hours, and of three fourths in twenty-four hours.

It was also succeeded by a sudden fall of the thermometer amounting to 20° and 30° in a few hours.

The difference of barometric pressure on the east and west side of this vein of snow caused no doubt by the difference of temperature, was sufficient to produce the violent westerly wind, on the west side of the vein of snow: and as the air in front of the vein was calm or nearly calm until within a few minutes before the westerly wind commenced with violence, it is manifest, the air east of the vein, on the approach of the westerly gale, which indeed was the most violent in five minutes after it commenced, must have ascended; and when it reached a certain height, it would form a cloud and give out its latent caloric of elasticity and of fluidity, which would expand the air in the cloud, after allowing for the condensation of the vapor nearly eight thousand cubic feet for every cubic foot of water thus formed and congealed into snow. This great expansion would cause the air to swell up to a greater height on the east side of the central line of the storm than on the western side.

The air, then, in the upper part of the atmosphere would roll off from the east towards the west, diminishing its weight on the east of the central line, and increasing it on the western side; and its violence would be augmented, or diminished, as it passed over the country with a higher or lower dew point. Moreover, the particles of snow would be carried up to a great height by the ascending air, on the east side of the central line, and thus become excessively cold, and in falling down through the air on the west side, would diminish its temperature very much, and cause the barometer to rise, on the west side, both by their own weight, and by the increased weight af the air, by cold.

142. This cold air covered the whole country from Michigan to the eastern coast of the United States, till the beginning of the great storm of the 26th January; and, what is worthy of particular notice is, that the temperature began to increase first in the north and north west. On the morning of the 25th, in the north western parts of Pennsylvania and northern parts of New York, the thermometer had already risen in some places 30°, and in others above 40°. While in the south east corner of Pennsylvania and in the south east corner of New York, it had not begun to rise. The wind also began to change from the north west to south and south east, first in the north west parts of Pennsylvania and New York, some time before it commenced in the south east of those states; and during the whole of the 25th the thermometer in the north of New York continued to rise, though the wind was blowing from the southward, where the thermometer was many degrees lower. What was the cause of this sudden increase of temperature in a

region bordered on the south with cold air, on the morning of the 25th, when the thermometer had already risen at St. Lawrence, in the north, from — 17° to + 27°; while it yet stood in the south east part of New York, at Clinton Academy, + 10°, and at Mount Pleasant + 8°? Was it the evolution of latent caloric in the incipient storm, then approaching from the north west? It might be objected to this suggestion, that the latent coloric is given out in the region of the clouds, and not in the lower air at the surface of the earth, and that, as air is a bad conductor, it could not convey the caloric down so as to affect the temperature. To this I answer, that though air is a bad conductor, or even a non-conductor, yet it must have the power of radiating caloric, or it would never get rid of the latent heat which it always receives in the formation of clouds. Nothing is more common than for the temperature to rise rapidly on the approach of a great snow storm.

143. It seems highly probable that this rise is partly due to the increased temperature and increased radiation of the upper air, which has then spread out over our heads from the approaching storm. Further observations are much to be desired on this point.

144. If the storm *commenced* in the neighborhood of the great lakes, and did *not* come from a great distance through Upper Canada, no doubt the upmoving column of air originated there from the greater heat and higher dew point of the air in contact with the waters of those lakes, which at that time would be 30° or 40° warmer than the air all round those lakes. This circumstance would only account for the commencement, but not for the continuance of the storm, nor for the increase of temperature round its southern borders.

Storm of the 15th December, 1839.

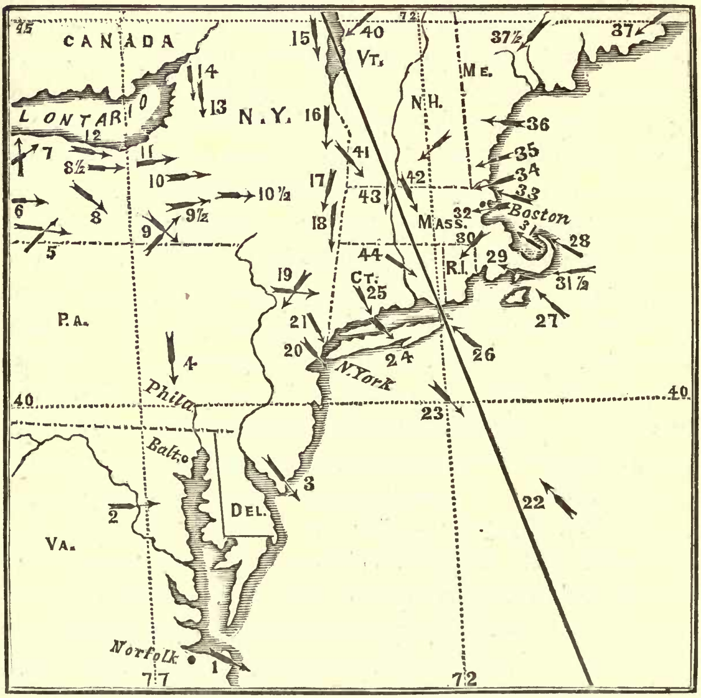
145. The following documents will show, that a storm of uncommon violence sprung up on the night of the 14th December, 1839, in the territory between Lake Erie and Boston, reaching from Montreal, down through Vermont, Massachusetts and Rhode Island, into the ocean to an unknown length.

As the wind was the most violent about one o'clock, on the eastern side of the storm — at Nantucket and Provincetown for example — and as the centre of the storm had certainly not passed those places at this time, I have chosen this hour to represent, on the following chart, the direction in which the wind was blowing at various places in the region of the storm, and near its borders.

If the reader will cast his eye on the chart, he will perceive at a glance, that if a line be drawn from Lake Champlain to the eastern end of Long Island and prolonged into the ocean, there is a general tendency of the winds, both on the Atlantic coast and in the western parts of New York, towards this line. Especially if he turns his attention to numbers 26, 27, 28, 29, 30, 31, on one side, and to 41, 42, 43 and 44 on the other, he will see a remarkable convergence of the winds towards a region between New Haven and Boston. Let the reader compare this fact with the statement of Mr. Redfield. "To me it clearly appears that the wind was not blowing at any time on the 15th towards a space or region of country south west from Boston and north east of New Haven, as was suggested by Mr. Espy in the Courier and Enquirer, and the New York Gazette, nor indeed towards any other central space in the gale."

This storm did not come from the far west, but originated in the territory above named. Its middle seemed to be almost stationary for twenty-four hours, gradually going off, however, in some east or south east direction.

Mr. Redfield adds, that "the whole series of gales, which have occurred weekly since the 24th of November, are well worthy of the attention of meteorologists; and the rotative character of each has appeared to be developed as clearly as in the case now before us." I think the truth of this statement quite probable, and I should be much gratified if Mr. Redfield would lay the evidence which he has collected before the public. I will aid him all I can in generalizing the facts.



EXPLANATION OF WOOD CUT.

No.
1. Norfolk, wind N. W. Keen and clear all day.
2. Washington, W.
3. Cape May, N. W.
4. Harrisburg, N.
5. Concord, N. Y., S. W., A. M., W, P. M.
6. Fredonia, W. all day.
7. Lewiston, S. W., A. M., S., P. M.
8. Steuben, N. W. all day.

8½. Monroe, W. all day. 16th, N.
9. Homer, S. W., A. M., N. W., P. M. On 16th, N. W.
9½. Hamilton, W., A. M., N., P. M. 16th, W.
10. Utica, W. all day. 15th and 16th.
10½. Cherry Valley, W. all day, 14th, 15th, and 16th.
11. Oneida, W. all day, 15th and 16th.
12. Rochester, W. all day N. W. on 16th.
13. Lowville, N. all day, 15th and 16th.
14. Governeur, N. all day, 15th and 16th.
15. Plattsburgh, N. all day, 14th, 15th and 16th.
16. Granville, N. all day, 14th, 15th, 16th.
17. Albany, Eastward of North.
18. Lansingburgh, N. all day. 16th, N. W.
19. Newburgh, W., A. M., N. E., P. M.
20. New York, N. by W. strong A. M., N. W. by W. before sunset.
21. Mount Pleasant, N.W. all day 15th, 16th.
22. Schooner Velocity, on A. M. of 15th, wind S. S. E. and S. S. W.
23. Ship Monroe, at 9, A. M. of 15th, heavy gales E. S. E., at 11 hove to, W.N.W.
24. Smithtown, (Long Island, near middle,) N. E., A. M., N. W., P. M.
25. New Haven, N., or a little W. of N. all the morning; in afternoon more to the west.
26. Thirty miles south of Block Island, E. southerly, moderate gales, and strong breezes.
27. Nantucket, E. all morning; at 1, P. M. violent, S. E. On 16th, N. E.
28. Provincetown, from 11 to 4, P. M., most violent, E. S. E.
29. New Bedford, E. all morning, E. very high at 2, P. M., S. S. E. high, at sunset.
30. Woonsocket, N. E. till 6, P. M., then E. Great storm, 3¾ inches when melted. N. E. on 16th.
31. Capt. Slemmer, E. S. E. a hurricane at 2, P. M. E. S. E. all morning.
31½. Schooner Friend, Capt. Ed. S. Johnson, U. S. N. E. N. E., all morning very violent till 3, P. M. On 16th, N. E. by N., heavy.
32. Boston, E. N. E., violent at noon; at sunset E. S. E., violent.
33. Gloucester, E. S. E., most disastrous gale.
34. Newburyport, between E. and N. E. a perfect hurricane in the night of 15th.
35. Portsmouth, E., or N. of E. during the day, heavy gale.
36. Portland, Me., E. at 11, and at 12 hard gale; all afternoon E. by S. to E. N. E. On 16th, north east storm.
37. Eastport, N. E. all 15th and 16th. Journal of the weather in the Eastport Sentinel. 16th, N. E.
37½. Waterville, N. E. all day. On 16th, N. N. E.
38. Concord, N. H., N. E. strong; afternoon very violent, N. of N. E.
39. Springfield, N. H., N. of E. all day; 15th, 16th and 17th, mostly heavy snow all the time.
40. Burlington, N. E. all day; on 16th, N., very gentle—twenty inches.
41. Bennington, N. W. all day 15th and 16th
42. Amherst, W. of N., wind and storm all day 15th and morning of 16th.
43. Northampton, N. all day 15th and 16th.
44. Hartford, N. W. during the whole day, in evening varied a point towards N.[1]

146. This storm continued to rage with violence in New Hampshire and Maine, all night of the 15th, and even increased in force on the morning of the 16th at Boston and in the region south and west of Boston, where it continued to snow most of the day. The centre of the storm seems to have made but little progress towards the east, if, indeed, the storm of 16th was not rather a renewal of the storm nearly in the same locality, for it continued to snow over almost the whole territory from the western part of New York, to the eastern part of Maine. I have exhibited on the following chart, the direction of the wind on the morning of the 16th.

[1] For original documents, see Appendix.

If the reader will examine the documents, he will perceive that in the State of New York, the wind was westerly and north westerly, and that in Maine, New Hampshire, and the eastern part of Massachusetts and Nantucket, the wind was violent from the north east. How far the storm at that time reached into the Atlantic, our observations do not inform us. One thing, however, we are able to determine — that the region of observation on this day, was the northern end of the storm, and it appears plain that the middle line reached from Vermont down through Rhode Island into the ocean, and that on each side of this line, the wind was blowing towards the line — with few exceptions, in the middle region. Let the reader now consider that there had been an immense mass of snow falling for more than twenty-four hours at this time at some places, for example, Woonsocket, some distance south west from Boston, 3.50 inches of water, and that during all this time, on both sides of a middle line, the wind was blowing towards that line from Maine to the western part of New York, and he will find in this storm, much to confirm the theory advocated in this book. It seems highly probable also, that this storm moved towards the south of east. For the barometer had risen on the morning of the 16th at Dorchester, near Boston, more than a quarter of an inch from midnight, while at New Bedford, it had risen only three hundredths of an inch, and at Nantucket, it had fallen a little during the same time. Besides it ceased to snow at Waterville, before it ceased at Portland, or Boston, or New Bedford, and many hours sooner than at Nantucket. And it does not appear that there was any snow on the 16th at Montreal, though there was on the 14th and 15th.

I am, perhaps, the more ready to believe, that this storm travelled towards the south of east; because by examining a great many extensive barometric fluctuations, I find they generally travel in that direction, and it is known that these fluctuations accompany storms. Reader, is it not worthy of consideration that while the barometer was very low for more than twenty-four hours in the central parts of Massachusetts, Connecticut, and Rhode Island, and a mighty snow falling especially there — the wind during all this time on the north east of this region, was north east, on the north of it, north, and on the north west of it, north west?

Let the reader also look at the Dorchester Journal, in the vicinity of Boston, and he will find the wind at sunset was violent E. S. E., instead of E. N. E., as Mr. Redfield infers it was at that time.

SECTION FIFTH.

EXAMINATION OF REID'S, PIDDINGTON'S, AND LOOMIS'S STORMS.

Colonel Reid's Storms.

147. PRESIDENT A. D. BACHE, on his return from Europe, put into my hands a highly interesting work by Lieut. Col. W. Reid, C. B., of the Royal Engineers, being "An attempt to develop the law of storms, by means of facts, arranged according to place and time, and hence to point out a cause for the variable winds, with a view to practical use in navigation."

This work is illustrated by charts showing the direction in which the various storms investigated moved along the surface of the sea, and showing the locality of the ships whose logs are given in the body of the work.

This work furnishes many additional proofs of that beautiful generalization first hinted at by Franklin, afterwards by Dr. Mitchell, of New York, and lately established in the most satisfactory manner, according to the true principle of inductive philosophy, by William C. Redfield, of New York: namely, "*Great storms which originate in the Windward Islands of the West Indies; progress from the place of commencement in a curve towards the N. W., till on reaching the lat. of* 30° *N., when they are moving nearly towards the N., their motion after this is towards the N. E. as far as traced.*" [1]

[1] Perhaps they sometimes turn E., or even S. E.

From all the facts collected by Mr. Redfield, by the Joint Committee of the American Philosphical Society and the Franklin Institute, and by Col. Reid, it would seem that these storms constantly become wider and wider, from their place of commencement, and perhaps elongated in their N. E. and S. W. diameter after they reach a lat. as high as 40° or 45°.

Col. Reid agrees with Col. Capper and Mr. Redfield, that these storms are in the form of great whirlwinds; and Sir John Herschel, who is of the same opinion, "does not see how Mr. Espy's theory, though he considers it ingenious, is tenable against the indications of the barometer, for, unquestionably, if a large body of air, he says, were to set on every side inwards towards a central ascending column, the necessary effect would be an increase of weight of the entire barometric column."

Now this objection is so obvious, that any theory, which has no answer for it, or which does not contain an answer to it in itself, does not deserve the name of ingenious; and it arises from so imperfect or inaccurate a view of the doctrine which I teach, that I am sure as soon as Sir John shall read my papers on the subject, he will see and confess that the objection has already been fully answered. If I am right in this matter, Sir John owes it not merely to me, but to the cause of science, on a point which he acknowledges to be of immense importance, to come out and correct his mistake; for such is the weight of his name, that many will not think it worth while to examine a system which has been condemned by Sir John Herschel.

As to Col. Reid, his whole book is a proof that he is much fonder of truth than of theory. He will therefore do me justice. I was highly delighted when this book came into my hands; for I saw immediately that it contained a great many facts and simultaneous observations, which would enable me at once to put my theory to a very severe test.

On reading the logs of the several ships, I kept the map of the particular storm open before me, and, drew my pencil across the point where the ship was, drawing an arrow so as to exhibit to the eye which way the wind was blowing at that time in that locality.

When several logs were read, and arrows made in every locality, I was not a little pleased to see, in all the storms, decided proofs of an inward motion of the air, if not exactly to one common centre, quite as nearly so as any one had a right to expect; because oblique forces are known to exist, which must vary the direction of the wind. I shall now give a few examples of that period of the several storms, in which I find the most simultaneous observations.

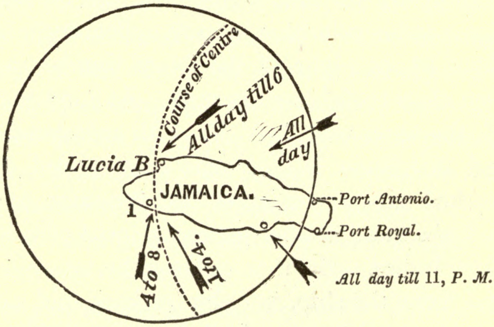
Savannah la Mar Hurricane of 3*d Oct.* 1780.

148. About 1, P. M., at Savannah la Mar, on the 3d, the gale began from the S. E., and continued with increasing violence until four in the afternoon, when it veered to the S., and became a perfect tempest, which lasted in force till about eight; it then abated. The sea, during the last period, exhibited a most awful scene; the waves swelled to an amazing height, rushed with an impetuosity not to be described on the land, and in a few minutes determined the fate of all the houses in the bay.

Log of the Badger, at Lucia Bay, Jamaica.—P. M., of 2d, moderate wind, N. E., at 9, hard rain, and continued raining all night, with squally weather; at 10, A. M., of the 3d, tripped our anchor, let her drive within the point of the Fort till it bore N. by E., distant three-quarters of a mile, and the eastermost N. E. by N., distance one mile and a half; heavy squalls with hard rain; down top-gallant sails. 1, P. M., wind N. E., let go the sheet anchor in five and a half fathoms; muddy; veered the cable, and brought both anchors ahead; continued very heavy gales with hard rain. At 4, let go another anchor. At 3.30, both sheet and bower anchors came home; veered away the clink round the mast, when the best cable parted, and then immediately the sheet cable parted likewise. At 5, she was driving on shore very fast, when a gust of wind laid her down, with the comings of the hatchway in the water. By consent of the captain and officers, cut away the weather halyard to the main shrowds, when the main-mast went about twenty feet above deck; she immediately righted, and drove broad-side on shore, abreast of the town; the sea making a free passage over us, when our boat went to pieces along side. At 5.30, cut the bower cable to let her swing end on. About 6, it fell calm for half an hour, when the wind shifted round to S. W., blowing a hurricane with strong flashes of lightning. At 10, it became quite moderate.

The Phœnix, off Port Antonio.—When the Phœnix was in company with the Barbadoes, off Port Antonio, the wind began to blow, with a stormy appearance, to the eastward, about 11, at night, of the 2d of October, and the Phœnix then close reefed her top-sails. At 8, on the morning of the 3d, the wind was E. N. E., with occasional heavy squalls; and Sir Hyde Parker, who commanded the Phœnix, remarked that the weather had the same appearance as he had observed in the commencement of a hurricane in the East Indies. He then ordered the top-sails to be taken in, and wore the ship, in order to keep mid channel between Jamaica and Cuba. At 2, P. M., the Phœnix lay-to, with a storm mizzen stay-sail, and her head to the northward. When night set in, the storm increased with great violence. At midnight, the wind was south east, and the ship drawing upon Cuba, Sir Hyde Parker determined to wear her, but no canvass could withstand the wind at this time, and she was wore by sending two hundred of the crew into the fore-rigging. When about to cut away the masts, the ship took the ground on the coast of Cuba; and it was 5 o'clock in the morning of the 4th of October.

Journal of Princess Royal, in Port Royal Harbor. — On 2d October, the wind was S. E. and E. S. E., A. M., and the people employed in caulking the ship's bottom. P. M., the wind was S. E. by E., and squally weather with rain; people employed as before; violent squalls with heavy rain in the night, wind from the south-eastward. On the 3d, A. M., the wind E. S. E. to S. E., and gale increasing with much rain; people employed in securing the ship; by the violence of the wind in the night, the mizzen-topsail, fore-top-gallantsail, and main-top-gallantsail, that were covering tents in the yard, and had been condemned by survey on the 30th of September, were entirely blown to pieces. P. M., wind S. S. E., and excessive hard squalls, with thunder, lightning and rain; people employed as before. At midnight, more moderate and light rain.



1. *Savannah la Mar; destroyed, Oct.* 3, 1780.

These are all the data we have concerning this storm, yet it will be seen, though we have no observations on the western half of this storm, that the centre of it passed over Lucia bay, from 6 to 6½, P. M., and at that very time, and for some time before and after, the wind on the other side of the island at Savannah la Mar, was blowing a hurricane from the south, exactly towards Lucia bay. The wind also at Port Royal, in the south east corner of the island, was blowing nearly to the same point, and from the log of the Phœnix, some place between the east end of Jamaica and Cuba, the wind was violent E. N. E., almost exactly towards Lucia bay. The reader will observe that when the wind changed at Lucia bay, and with the Phœnix, all the four arrows, if drawn on the chart, would point to a spot near where the Phœnix was wrecked, not many hours afterwards, on Cuba.

Great Barbadoes Hurricane, of October 11, 1780.

149. At Carlisle bay, on the west side of Barbadoes, it was remarkably calm on the evening of the 9th October, but the sky was remarkably red and fiery. During the night, much rain fell. On the morning of the 10th, much rain and wind from the N. W. By 10, it increased very much. By 4, P. M., the Albemarle frigate parted and went to sea, as did all the other vessels, about twenty-five in number. By 10, P. M., the wind forced itself a passage through the house from the N. N. W., and the tempest increased every minute.

At St. Lucia—All the barracks and other buildings in the island were blown down.

At St. Vincent—Every building was blown down.

At the town of St. Pierre, in Martinique—Every house was blown down, and more than one thousand people perished.

At Fort Royal—Fourteen hundred houses, besides the churches and public buildings, were blown down.

At St. Eustatia—On the morning of 10th, at 11 o'clock, the sky on a sudden blackened all round; it looked as dismal as night, attended with the most violent rains, thunder, and lightning ever known before. In the afternoon, the gale increased. In the night, every house to the northward and southward was blown down or washed away into the sea, a few only escaping. The houses on the east and west were not so much hurt, till the P. M. of the 11th, when the wind, on a sudden, shifted to the eastward; and at night it blew with redoubled fury, and swept away every house.

At Barbadoes — It began to blow on the 9th, but on the evening of the 10th the wind rose to such a degree of violence as clearly to amount to what is called a hurricane. At 8, P. M., it began to make impression on all the houses by tearing off the roofs, and overthrowing some of the walls. It was thought to be at its greatest height about midnight, and did not abate considerably until 8 next morning.

Log of the ship Albemarle, lying in Carlisle Bay, on the west side of Barbadoes. — On the afternoon of the 9th, wind E., moderate and hazy. Morning of 10th, E. N. E., blowing very hard. At 1, P. M., N. E. by N., strong gales with hard rain at times. The gale increasing, the officers decided to go to sea, which was done at 2, P. M., wind N. N. E. At 30 minutes past midnight, still blowing a hurricane, with rain, and wind shifting to westward. At 5, in the morning of 11th, the wind shifted round to the southward, still blowing very hard, with constant rain. At noon, still blowing a hurricane, with hard rain. P. M., still blowing a hurricane, with wind S. E. by S., with constant heavy rain. At 4, saw the north west end of Barbadoes, bearing N. E. by N., distance four or five miles. At 4.30, wind shifted round to S. E., and heavy gales of wind with constant rain. At 5, A. M., of 12th, more moderate, but fresh gales continued S. E., in P. M.

Log of the Vengeance. — Moored in Careenage, on west side of St. Lucia. Dark cloudy weather on the afternoon of the 9th. The Blanche and Alcmene sailed at 6, A. M., of 10th. On the afternoon of 10th, strong squalls; at 7.30,

P. M., very strong squalls, variable. At 9, P. M., the Ajax parted her cables and went out to sea. At 11, the gale increased very much. At 12, the Egmont slipped and went out to sea — wind variable all this time. At 4.30, A. M., of 11th, the Montagu slipped and ran out to sea. At 8.30, wind N. E., and the Amazon slipped and ran out to sea. Several transports drove on shore and dismasted in the harbor. At noon, violent squalls and N. E. At 12.15, parted the small bower and brought up with the stream and sheet anchors. . . . . Cut away the long boat, cutter, and schooner tender, which were immediately dashed to pieces; the hurricane still increasing and the ship striking at times. At 8, wind N. by E., and veering round to eastward. At 9, lightning between the squalls, still blowing excessively hard, with rain. At 10, less wind with more rain and lightning. At 12, the hurricane abated with rain. At 4, on morning of 12th, strong gales and squally, with heavy rain. At 11, A. M., wind E. S. E. In the afternoon, wind E. S. E., moderate, with rain. At 8, thunder and lightning and rain.

Log of the Alcmene. — At 1, P. M., of 10th, wind N. N. E., fresh breeze and squally. At 2, P. M., got under way from the Careenage in St. Lucia, in company with the Blanche. At 5, P. M., N. ½ E., Martinique E. ½ N., 6 leagues. At 8, N. by E. At 10, N. N. E. At 3 in the morning of 11th, N. by E., hard gales and rain. At 7, N. N. E. At 10, very hard gales and rain; great sea. At 1, P. M., hard gales and thick weather with rain, wind variable. At 4, lost sight of the Blanche bearing S. S. E., half a mile. From 5 till 9, wind N. W., and gale increasing. At 12, gale still increasing, and wind S. E., from 10. At 3, A. M., of 12th, wind S. W. At 7, wind S. by W. At 10, gale abated, saw a ship ahead, supposed to be the Blanche. At 1, P. M., wind S. S. E., fresh gales and squally. At 3, P. M., wind S. E. At 10, saw Martinique E. by N., 5 leagues.

Log of the Egmont. — At 10, A. M., of the 10th, squally and wind variable. At 12, northwardly, squally and hard rain, sailed from the Careenage in St. Lucia in company with the Blanche and Alcmene. At 1, P. M., wind N. by N., fresh gales and squally, with rain. At 6, P. M., E. N. E. At 7, came on a heavy squall of wind with rain, which parted the small bower cable at twenty fathoms from the anchor. At 9, wind N. At 10, N. by W. At 11.30, cut away the best bower at a whole cable and went to sea. Midnight, N. E. by N., split the main top-mast-stay sail. At 4, A. M., of 11th, strong gales with hard squalls of rain. At 7, carried away the main-stay sail. At 8, A. M., wind N. by W. At noon, St. Lucia, N. 19° E., distance thirteen leagues. At 1, P. M., of 11th, wind N. E., very strong gales with hard squalls and rain. From 10 at night, till 8 next morning, while the storm was most violent, the wind was from all quarters. It then became S. S. E. and S. E., and so continued till the end of the storm. At noon, of 12th, St. Lucia, N. E. by E. ¾ E., distance eleven leagues.

Log of the Montagu, lying off the entrance of the Careenage, St Lucia. — On P. M., of 10th, wind N., strong gales with heavy squalls of rain and a heavy swell from N. W. At midnight, parted or slipped ship Ajax. At 3, A. M., of 11th, slipped and put to sea the ship Egmont. At 5.30, in preparing to slip and put to sea, we parted our stream and small bower cables; stood out W. N. W., till 8, A. M. South end of St. Lucia, then bore S. S. E., nine or ten leagues, wind N. N. E., brought her to with her head to the northward, up N. W., off W. by N., very strong gales. At 1, P. M., wind N. N. E., a very heavy storm, with rain. At 3.30, in cutting the main and fore-topmast, the main-mast, fore and mizzenmast, all went over the side; a heavy storm of rain. At 4.15, the bowspit went by the outer gammon, and carried away the greater part of the head.

At 6 and 8, wind N. by W., weather the same, and very high sea. At 5, A. M., wind W. S. W. and more moderate. At 9, A. M., saw the Sugar Loaves of St. Lucia bearing E. ½ N., distance four leagues; the Island of St. Vincent then E. S. E., distance six leagues. At noon, moderate breezes and high sea, cloudy with rain — Sugar Loaves E., distance two leagues.

Log of the Amazon, in the Careenage. — On the afternoon of 10th, fresh breezes with hard squalls. At 6, P. M., the Egmont parted, and brought up again under our stern. At 9, the Ajax put to sea. At 11, the Egmont cut and put to sea; excessive hard gales with rain. At 4, A. M., wind northeasterly, the Montagu parted and put to sea. At 7.30, finding the gale increase, slipped the small bower and stream cables, and cut the best and put to sea. Noon, blowing a hurricane with a heavy sea. At 2, P. M., blowing a perfect hurricane N. E. At 7.30, by the violence of the hurricane, the ship overset, and lay in that situation 7 or 8 minutes. At 8, the wind N. W., and ship quite righted with 10 feet water in the hold. At 2, A. M., of 12th, pumps choaked with seven feet water in the hold. At 4, A. M., found the wind abate. At noon, wind N. N. W., gale much abated. In P. M., wind E. by S., first part hard gales with rain. At 5, wind had been quite round the compass in the last twenty-four hours. On the afternoon of 13th, wind still E. by S., with fresh gales and hazy weather with rain. At 6, the body of Martinique E. by S., distance eight or ten leagues.

Log of the Endymion, N. N. E. of Martinico. — On the afternoon of the 10th, wind N. E., strong gales and hard squalls. At 4, saw the N. E. end of Martinico S. W. by S., distance seven leagues. At midnight, strong gales continue. At 8, A. M., of 11th, wind E. N. E., heavy gales and strong squalls. At noon, blows strong and violent squalls, N. E. end of Martinico W. S. W., distance four leagues.

At 1, P. M., wind E. N. E., strong gales and hard squalls. At 3, A. M., of 12th, just weathered the Island of Caraval, the N. E. end of Martinico. At 5, the wind E. At 7, wind E. by N., hove to under a mizzen topsail. At noon, wind E. S. E., continuing a heavy gale and violent squalls. N. end of Martinico, distance fifteen leagues.

To these particulars extracted from Col. Reid, I am enabled to add the following from the Pennsylvania Gazette of 1780.

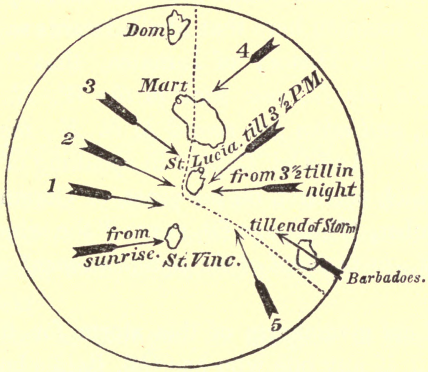
Pennsylvania Gazette of December 13, 1780.—At Bridgetown, Barbadoes, (which is on the south west side) the wind began to blow very fresh soon after daybreak of Tuesday the 10th of October, and increased till 4 o'clock next morning. The wind during the greater part of the hurricane, blew from the N. E. quarter, and never shifted to the southward further than S. E.

From the same paper of December 6. — On the 10th, at St. Pierre, on the west side of Martinique, a sudden gale sprung up from N. E., and though the gale increased and continued without intermission, the shipping kept their stations as the wind blew off the land till the 11th. On the night of the 11th, the wind shifted to the southward, and after continuing there two or three hours, shifted to the S. W., and blew right on shore. Between 2 and 3 o'clock of the morning of the 12th, the sea was thrown into the most violent agitation, and raged with incredible fury, and destroyed many houses and stores on the bay.

At St. Christophers, the wind abated on Saturday, the 14th, but about 8 o'clock, it changed to the southward, and drove the Minerva on shore. At Bassatere, St. Christophers, it began a gale about midnight of Wednesday the 11th, and increased all next day.

Same paper of December 20. — At St. Vincents, the wind came round to N. W., on Tuesday night the 10th, and blew very fresh all night from that quarter. At sunrise, it came rather more to the westward, and the gale increased, and from 12 till 4, P. M., there never was such a scene. The wind began to abate at 5, P. M.

Chart of the Great Barbadoes Hurricane, October 11*th*, 1780, *showing the course of the wind at* 6, *P. M.*



1. Montagu from 6 to 8, P. M.
2. Amazon at 2, P. M.
3. Alcmene from 5, till 9, P. M.
4. Endymion from P. M. of 10th to 12th.
5. Albemarle from 4½, P. M., till next day.

The dotted line is the course which the centre of the storm moved in.

By casting the eye on the map which is intended to represent the locality of the storm at 6, P. M., of the 11th, it will be seen that all the arrows fairly within the action of the storm are directed inwards to a central space of no great magnitude.

This action lasted for several hours of the evening of the 11th; and did not vary until the centre of the storm, towards midnight, passed the Alcmene, the Egmont, and the Montagu, in its motion towards the N. W. And it is worthy of particular remark, that as the storm passed on, the wind to all these vessels, changed round to the S. E., as it had already done at Barbadoes, and to the Albemarle, near Barbadoes.

Now as the centre of the storm passed over or very near all these places, it will readily be perceived that the manner in which the wind changed, accords exactly with the idea, that the wind blows inwards towards the centre of these storms; and not at all with the notion that it blows in the form of a whirlwind. When I take up some of the other storms, I shall notice this fact more particularly. I shall only mention here that Mr. Edwards says, in the third volume of his History of Jamaica, that "*all hurricanes begin from the N., veer back to the W. N. W., W., and S. S. W., and when got round to S. E., the foul weather breaks up.*" And Col. Capper in speaking of a great hurricane which occurred on the coast of Coromandel, on the 29th October, 1768, page 60, says: "the wind began from the N. W., *as is usual at the commencement of these hurricanes.*"

I shall not give charts of this storm for the subsequent days; but if any one who has Col. Reid's book, will read the logs of the Endymion, and the Convert, and the Egmont, and the Diamond, for the 15th and 16th, he will find, if he draws arrows on the charts representing the direction of the wind on these several days, a remarkable convergence towards the centre of the storm. And if he extends his observations to the 17th and 18th, he may include the Grafton, with the ships mentioned before. Now as these ships were several hundred miles apart, the evidence is conclusive, that on all these days the wind did blow inwards to the centre of the storm.

But there is one remarkable feature in this storm which must not be passed over in silence. Its centre in its motion turned out of its regular course and passed over Martinique, a little after midnight of the 11th. At this time the Endymion, on the N. N. E. of that island, had the wind violent from the E. N. E.; and at St. Pierre, on the south west side of the same island, the wind was S. W. And the

Alcmene, some fifteen or twenty miles to the S. S. W. of the island, had the wind S. W. to S. S. W., about the same time for several hours. The intelligent reader will perceive how the wind from the N. E. striking on the eastern side of this island whose mountains are of considerable height, would glance upwards, and thus form a cloud over the island, and thus cause the centre of the storm to locate itself for a time over that island.

Antigua Hurricane of 2d August, 1837, *at Antigua.*

150. On the 2d of August, between 2 and 3, A. M., we had a smart gale from north, which crept gradually round by the north west, west, and south west, until it died away in the south east.

One barometer at Antigua, in the gale of the 2d, only sunk .43, another sunk .63.

At Nevis, on the morning of August 2d, between 3 and 4, the wind being north, a shower of rain fell. At half past 6, A. M., the wind began to rise until 8, it then shifted to the N. N. W., and gradually increased in gusts until 10, during which time much rain fell. The wind then veered to the westward, and next to due south, then back to south west, and last backed to south again, from whence it blew steadily and with violence until 2, P. M., when it abated.

At St. Kitts, early on Wednesday morning, the 2d of August, the wind blew strong from the north, and indicated the forthcoming storm. At about 8, A. M., it veered to N. W., and shortly afterwards to west, during which time, it blew a perfect gale, throwing a tremendous sea into the harbor, and threatening the destruction of every vessel.

At St. Bartholomew, the storm commenced at north east, and continued to increase in violence until 2, P. M.

At St. Martin, a gale commenced about 9, A. M., and raged with great violence from 11, A. M., to 2, P. M., veering from E. N. E., to N. W.

At Santa Cruz, on Monday the 31st July, 1837, the weather was moderate; several ships sailed on Tuesday, the 1st of August; in the evening, the wind was north east, and the weather moderate. On Wednesday, the 2d, the wind during the night had shifted to the north; the weather looked squally, cloudy and suspicious, and continued so during the afternoon; the wind shifted gradually to the N. N. W. At 1, P. M., the falling of the barometer, the appearance of the weather, and the increasing wind, left us no doubt of the approaching storm, and it came on from the north west, between 3 and 4 P. M. The mercury continued falling, and the gale increasing, until half past 6, P. M., when the wind became westerly. At 7, P. M., the mercury began slowly to ascend, and yet the storm increased in violence. At 8, P. M., it was blowing a hurricane from the west south west, to the south west, coming in furious gusts until 10, P. M., when a certain decrease in their violence had taken place, which abatement continued until Thursday morning, the 3d of August, when it blew a fresh gale from the south.

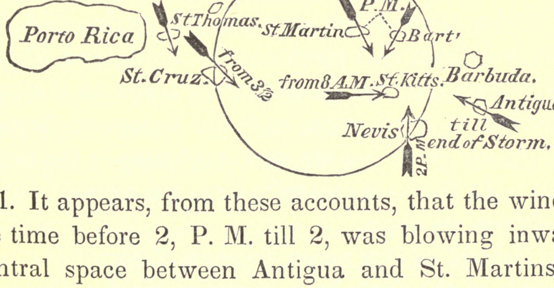
Log of the Water-Witch. — Arrived off St. Thomas on the 2d August; morning squally, and the Water-Witch was off St. John's, and standing for St. Thomas's, the wind N. and N. N. W. Noon, shipping in the harbor visible; at 1, P. M. squalls violent; at 3, P. we had beat up within half a mile of the forts, when we could proceed no further from the violence of the squalls, and anchored in ten fathoms water; sent down top-gallant-yards, &c.; did not suspect a hurricane. At 5, P. M. squalls ceased, and began a heavy gale of wind, at that time off the land. At 7, P. M. a hurricane beyond all description, dreadful; the windlass capsized, and I could not slip my cables, ship driving until I was in twenty fathoms water; a calm then succeeded for about ten minutes, and then in the most tremendous unearthly screech I ever heard, it recommenced from the S. and S. W. I now considered it all over with us, for the wind was directly on shore, and the sea rose and ran mountain high. At 2, A. M., the gale abated somewhat, and the barometer rose an inch; at daylight, out of forty vessels, the Water Witch and one other were the only two not sunk, ashore, or capsized.

Porto Rico. — At 4, P. M., on the 2d of August, 1837, in consequence of having observed the barometer falling, I ordered all the vessels in the harbor to prepare for stormy weather, although the fall of the barometer was not great.

At 8 P. M.	barometer	at 29.6	At 12, midnight,		barome.	28 00
9	"	" 29.5	$1\frac{1}{2}$ A. M.		"	29.17
10	"	" 29.4	4	"	"	29.50
11	"	" 29.3				

At 9, P. M. the wind was strong N. N. E. At 11 veering to east, and blowing in an alarming and furious degree till midnight, when every vessel was sunk or ashore. At 4, the wind fell, and then veered to the S.

Antigua Hurricane of 2d August, P. M., 1837.



151. It appears, from these accounts, that the wind, from some time before 2, P. M. till 2, was blowing inwards to a central space between Antigua and St. Martins, from four different localities, Antigua, Nevis, St. Martins and St. Bartholomew.

It is worthy also of particular remark, that the barometer fell at Porto Rico to 28 inches, and rose to 29.17 in an hour and a half. As this storm moved about 10 miles in an hour, it would appear that the barometer was lower in the middle of the storm by 1.17 inches than it was at the distance of fifteen miles, and if so, the velocity of the up-moving column in the middle of the storm may be calculated according to the laws of spouting fluids, and will be found to be upwards of 260 feet per second. From this the quantity of vapor condensed in a second may be calculated.

Barbadoes Hurricane of 26*th July*, 1837.

152. *At Barbadoes* — At 2 o'clock, A. M. of 26th July, light showers of rain, wind shifting from south to north west, the sky dark and gloomy, with flashes of lightning in the south east and south west. At 4, calm, with a heavy swell rolling into the bay; lightning and thunder, sky assuming a black appearance, with a red glare at the verge of the horizon; every flash of lightning with an unusual whizzing noise, like that of a red hot iron plunged in water; at 6, the barometer fell rapidly, the sympiesometer much agitated and unsettled, and fell at length to 28.45. At 7.30 the hurricane burst on us in all its dreadful fury; at 8 it shifted from east south east to south, and blew for half an hour, so that we could hardly stand on deck; the wind shifting to south west, at 9 the barometer began to rise, and to our great joy we saw a change in the sky for the better. As the haze cleared away, we counted twenty-one sail driven on shore.

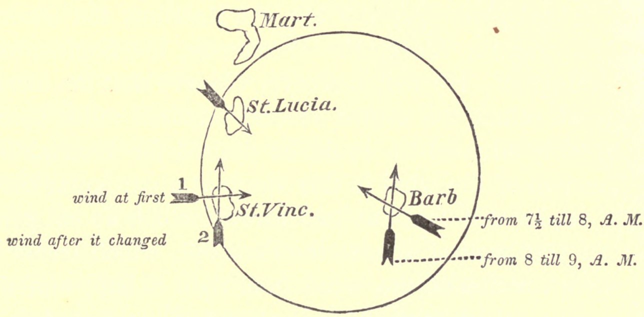
At St. Vincent. — Our paper from St. Vincent informs us that the gale of the 26th July was severely felt there; the wind being from the west and south with a heavy swell of the sea.

At St. Lucia. — We have experienced a severe gale from tae north west, which lasted several hours.

At Martinique. — Martinique suffered a severe gale on the 26th July, from the south east. The tempest raged there at 10, P. M., at which hour all was calm at Barbadoes.

When the storm was raging at Martinique, it was calm at Barbadoes.

The wind at Barbadoes commenced from the N. W.



153. It is evident that the wind in all these four storms, blew inwards from the circumference towards a central space of no great magnitude. I shall at some future time examine the other hurricanes in which simultaneous observations can be found, and I hope to show some strong cases in favor of an inward motion. There is one which I have already examined, which is more striking than any of the four here given; I mean that of the 18th of August, 1837. I have been able to add from the American newspapers some observations on that storm, which will render the phenomena much more striking. These observations are copied here for the sake of those who may have Col. Reid's book, who can then examine the storm for themselves.

The *Philadelphia Commercial Herald*, of 28th of August, says, " barque King Philip on the 18th of Aug. lat. 31° 12′, long. 78° 16′, gale from N. N. E. to W. N. W."

The same paper of 29th of August, says, "brig Oglethorpe, on the 18th August, lat. 32° 29′, long. 78° 55′ had a violent gale from N. W."

If the reader will now turn to Col. Reid's account of this storm, and mark with his pencil on the chart the direction of the wind on the 18th of August, 1837, he will find that the arrows of the following places all point inwards, towards a space where the West Indian and the Duke of Manchester were laboring in the centre of the storm at that time. The Oglethorpe, the Ida, the Rawlins, the Cicero, the Delaware, the Mary, the Westbrook, the Sophia, and at Wilmington. He will moreover observe that the localities are all round the centre, several hundred miles apart, as favorably situated as could be desired for ascertaining the direction of the wind in this storm at a particular time.

The reader will find but two arrows which do not point towards this central space; the Penelope, which seems to indicate a rotation of the wind from right to left; and the Winchester, which seems to indicate a rotation from left to right. These anomalies I hope to explain satisfactorily, and in such a manner as to add a strong link to the chain of argument in favor of an inward motion of the air towards the centre of the storm, if indeed any other evidence, than that of the fact itself, is necessary.

Now if the wind did blow inwards in all these storms, all the phenomena can be accounted for, from the single fact which I have demonstrated from experiment, as indicated in a publication of mine in the Saturday Courier of March 18, 1837.

For as the air must have moved upwards over a central space of undefined magnitude in all these storms, I have demonstrated by experiment that the cold due to diminished pressure, would condense one half its vapor when it reached six thousand yards, a quantity sufficient in ordinary states of the dew point to produce three inches of rain in that climate. The condensation of this vapor, as I have demonstrated by experiment, would give out into the air in contact with the condensing vapor, caloric of elasticity sufficient to expand that air between five and six thousand cubic feet for every cubic foot of water generated, after making allowance for the diminished volume due to the condensation of the vapor itself into water.

This will cause the barometer to fall more than two inches in the centre of the storm, and to rise all round on the outside of the storm, especially on that side towards which the top of the cloud is pressed by the upper current of the atmosphere into which the cloud penetrates; and that will be the direction in which the storm will move along the surface of the earth; all which I have elsewhere shown.

As the cloud moves along, being pushed by the upper current, the air under the cloud will, on account of the specific levity of the cloud, ascend, and thus the action will be continued. Moreover, I have demonstrated from experiment that if the barometer falls two inches under the base of one of these clouds, the air will not have to ascend so high, by eight hundred yards, before it begins, by the cold of diminished pressure, to form cloud; and this, in many cases, will bring the cloud down on the surface of the sea; or in other words the vapor of the air in the outside of the storm will begin to condense, as soon as it comes under the base of the cloud, from the cold produced by diminished pressure there.

154. It is not a little remarkable, that all these storms, and others which have been traced in the West Indies, travelled towards the N. W. almost at right angles to the direction of the trade wind in those latitudes; but very nearly, if not exactly, in the direction of an upper current of the air, known to exist there towards the N. W. The direction of the trade wind will therefore produce an oblique

force, which will cause the wind to set in at the beginning of these storms, not exactly towards the centre of them, but towards a point west of that centre, and if this single circumstance should be observed without attending to all the phenomena, it would undoubtedly give rise to a suspicion, that the wind in these storms rotates from right to left. And if to this circumstance be added, that these storms are nearly round in this latitude, and that the air at some moderate distance around them is nearly calm, the investigator will be confirmed in his first impression, and perhaps not even think it worth while to mark on his chart, by arrows, the course of the wind in the simultaneous observations at his command. And if to all this is added his belief, that the air in a cloud is denser and heavier than surrounding air at the same elevation, he will consider that it amounts to absolute demonstration, that there must be a whirl, as that is the only possible means of causing a depression of the barometer under all these circumstances, in the middle of the storm. Again, if he believes that the cold air from above, coming down in the centre of the whirlwind, which it would do, mingles with the warm air below, and thus produces condensation of its vapor, he thinks he has got hold of a fact, which enables him to explain many phenomena connected with the storm, though the whirlwind itself remains unexplained, as it always must. But if he will examine this subject a little more minutely, he will find, that if air should descend from a height sufficiently great to double its density at the surface of the earth, its dew point will be raised only 20°, and its temperature by increased pressure about 90°, and that it will then be extremely dry, even if it had been saturated at the commencement of its descent. In fact, it would then be able to contain about eight times as much vapor as it contained before its descent; for at these low temperatures every increase of temperature of 20° doubles its power of containing vapor, as may be ascertained by looking at a table of dew points. (129). In fact the doctrine of mingling air in the atmosphere to produce cloud, as taught by Dr. Hutton, will not stand the test of examination, even if a means could be discovered of producing the mixture. For it must be done either by cold air coming down, or warm air going up; now if cold air comes down, it becomes intensely dry, and if warm air goes up, it will condense its vapor by the cold of diminished pressure, and more so the less it mingles with the upper air. Nor is the doctrine that cloud is heavier than surrounding air at the same height tenable, as was shown before.

The question then resolves itself into a matter of fact; and a question of great moment it is acknowledged to be; is there a centripetal or a centrifugal motion of the air in these storms? If the former is true, all the phenomena are explained; if the latter, nothing is explained; not even the whirling motion itself. Let the careful reader decide.

Storm of September 3d, 1821.

155. The following investigation of the storm of 1821, was written early in the year 1838, and presented to the joint committee of the American Philosophical Society and the Franklin Institute by me, in my official capacity as meteorologist of that committee; but it was not accepted. I now publish it on my own responsibility; and as this storm has been copied by Col. Reid into his book, it may now be considered as a part of the examination of his law of storms, though it was written before his book was published. This much it was necessary to say in explanation of the peculiar phraseology of what follows, since it is published verbatim as it was read to the committee.

PHILADELPHIA, January 10th, 1838.

GENTLEMEN:—As the meteorological instruments (118) ordered by the Committee have not all been made, and distributed to the several counties of the state, and as recent materials have consequently not yet been furnished to your meteorologist for a report, I have thought it would be interesting and useful to the cause in which we are engaged, to investigate the phenomena connected with the GREAT STORM which visited our coast Sept. 3d, 1821.

I have chosen this storm in preference to others, because materials for its investigation are more abundant, and also because Mr. Redfield thinks " there is but one satisfactory explanation of the phenomena. " *The storm was exhibited in the form of a great whirlwind.*"

Now it is of immense importance to the mariner that he should have correct views on this point — and I propose to demonstrate that this storm at least was not exhibited in the form of a whirlwind, but was like the twelve storms which have been investigated by the Joint Committee of the American Philosophical Society and the Franklin Institute; that is, the wind blew inwards at its borders.

This conclusion is rendered certain by the following facts, which are deductions from the particulars given below.

1st. The storm set in every where on the extreme south east border from the south east, and not from the south west, and changed round to the S. S. W., or S. And on the extreme N. W. border it set in from N. N. E., and blew hardest from the N. and N. W. Now, on the extreme S. E. border it could not blow from the S. E. at all, on the supposition that it was a whirlwind; nor on the N. W. side, could it blow at all from the N. W. Both facts, however, are not only consistent with a centripetal motion of the air, but absolutely prove it.

2d. Wherever the wind set in from the E., it always changed round by the S., which is consistent with the cenpetal, and inconsistent with the centrifugal, theory.

3d. There never was a lull mentioned, only where the wind set in from the N. E., which has the same bearing as before, for the centre of the storm only can have a lull.

4th. Where the wind set in from the S. E., there is no lull mentioned previous to a change of wind, and in no instance could I find that it changed round to N. W. Two instances are given by Mr. Redfield, one at Bridgeport, Conn., which I find is incorrectly reported, and instead of changing round to N. W., it should read to S. W. — the other at sea, forty miles N. of Cape Henry; this I could not find, and I suspect there is something wrong in it, for forty miles N. of Cape Henry is not at sea, but in the eastern shore of Virginia. At other places in a right line with this, it set in from the N. E., *e. g.* at Cape May and Norfolk.

5th. Along the seaboard, where the wind had been S. and S. E. all day, at the approach of the storm, it backed round towards the E. and E. N. E.; and inland, where the wind had been N. W., it backed round towards the N. and N. E. on the approach of the storm.

6th. Wherever the wind set in from the N. E., it ought not to have changed at all, according to the centrifugal theory, whereas it did actually always change round by the N. to N. W. or W., or by the S. to S. W., as it should do by the centripetal theory.

7th. According to the centrifugal theory, the wind never could change round on the extreme N. W. boundary from the N. N. E. to the N. W., as it did, according to the centripetal theory.

8th. On the extreme S. E. boundary it could not blow at all from the S. E., according to the centrifugal theory: but it did, according to the centripetal theory, blow in that direction in many places on that border, for six or eight hours during the whole strength of the gale.

9th. On the extreme N. W. border, according to the centrifugal theory, it could not blow the hardest from the N. W., nor on the extreme S. E. border could it blow the hardest from the S. E., as it did, in exact conformity with the centripetal theory.

10th. At Cape May it changed round from N. E. by E., and at Cape Henlopen it changed round from N. E. by N., in conformity with the centripetal, and entirely contradictory to the centrifugal theory.

11th. Both in Norfolk and New York, the wind set in from near the N. E., and at the termination blew from the S. W., which is the experimentum crucis in favor of the centripetal theory, and utterly inconsistent with the other. In like manner at Ocracock, it set in E. S. E. and terminated S. S. W., and out at sea, in the extreme eastern borders of the storm, the wind blew for eight or ten hours from S. E. and S. by E., with but little change, as it ought to do, if the wind does actually blow towards the centre of the storm.

12th. At the time the wind changed round to S. S. W. at Ocracock, it was blowing at Norfolk a violent gale N. E., nearly towards Ocracock. Now as these places are 130 miles apart, and nearly on opposite sides of the storm at that moment, it is utterly impossible, according to the whirlwind theory, that the wind at Ocracock should be blowing towards Norfolk, and at the same time, the wind at Norfolk be blowing towards Ocracock. And this fact is entirely consistent with the centripetal theory.

The wind also changed round at Norfolk, S. W., before it set in from the N. E. at New York. Also two ships at sea, opposite the Jersey coast, had the wind blowing a gale from E. S. E. to S. S. E. At the same time, the wind was violent at Philadelphia and Reedy Island from N. N. E. to N. W. Now these places were nearly in opposite sides of the storm; the wind was therefore centripetal as it blew from each towards the other. Also, while the storm was passing over Connecticut, the wind blew constantly, in the S. E. corner, from the S. E., while at the same time, in the N. W. corner of the state, the wind was blowing a furious gale from the

N. W.; and Mr. Redfield himself testifies that the "trees and corn in this corner of the state were uniformly prostrated towards the S. E., while even as far inland as Middletown, they were uniformly prostrated towards the N. W."

"It appears," says Mr. Redfield, "that in the central part of the state of Connecticut, the mass of the atmosphere upon the earth's surface was moving for several hours, apparently towards the N. W., with a probable velocity of 75 to 100 miles per hour, while in the northern parts of Litchfield county, [that is, in the N. W. parts of the state,] at a distance of say 40 miles, the wind, at about the same period, was blowing with nearly equal violence towards the S. or S. E."

Now, as the wind at New York changed round to "S. W., and blew away the clouds with astonishing quickness," about the time that these currents of air were rushing towards each other, from the S. E. and N. W. of the state of Connecticut, we have three points, S. E. and S. W. and N. W. in the borders of the storm, from which the wind blew towards the centre. This fact alone would establish the truth of the centripetal theory, at least in this storm.

We have no account how the wind blew to the N. E. of the point in Connecticut, towards which these three currents blew, but as the wind set in from the N. E. in front of the storm wherever we have any account, it is highly probable that here too the wind was blowing from the N. E. at the same time.

We have, then, the most decisive evidence that the wind, during the whole progress of this storm along our coast, blew inwards, at its borders, towards its central parts.

I do not say that the wind blew to one central point from every part of the circumference — this is hardly to be expected, even if the storm was perfectly circular, for reasons too obvious to require explanation.

But it seems almost certain that the diameter of the storm was much longer from S. W. to N. E. than from S. E. to N. W. The wind was only beginning to abate at noon, to a ship 75 miles S. by E. from Cape Hatteras, and this was the time the storm was commencing at Reedy Island, not far below Philadelphia. The diameter of the storm, therefore, in this direction, was more than 300 miles, whilst its diameter from N. W. to S. E. could hardly have been half this quantity, for the storm was not felt at Wilmington, N. C. nor at Baltimore. And two ships off our coast, one from Charleston bound to the Chesapeake, and one from Boston to Norfolk, in latitude 40° 19′, did not experience the gale. And when the storm reached Connecticut, it certainly was not more than about 100 miles broad in this direction, for at Providence it was not of a violent character, and about fifty miles N. W. of that city, the centre of the storm passed, so that here its S. E. semi-diameter was only about fifty miles. Between the Delaware Capes, also, the centre of the storm passed; for the wind changed round by E. at Cape May, and by N. at Cape Henlopen —and as the storm did not reach Baltimore, its N. W. semi-diameter was not more than fifty miles.

The shape of the storm, then, not being round, as Mr. Redfield believed, is unfavorable to the whirlwind theory, and will satisfactorily explain the circumstance that the wind did not blow exactly at times towards one central point — there was no such *point*, the centre was a *line* of considerable length.

156. The hypothesis of a whirlwind in this storm is therefore not true in fact; and if it was true, it is totally incapable of explaining any of the phenomena.

It does not explain the cause of the rain and hail. For, if there was a whirlwind of such violence as to make the wind in the borders of the storm move with a velocity of 75 or 100 miles an hour at the surface of the earth, the air must have come downwards in the centre with very great velocity, a velocity calculated in article 88, unless the whirling motion extended to so great a height that the air at the surface of the atmosphere could not get in.

If indeed the rotary velocity was much greater in the middle region of the air than at the surface of the earth, or the upper regions, then the air would rush upwards below, and downwards above, towards the middle region, and the cloud there formed, if one should be formed, would be seen whirling round with great velocity and spreading outwards with proportionate rapidity. In this way, large quantities of the upper part and lower part would be mingled together —and it seems to be generally, though erroneously, believed, that the upper part, being much colder than the lower, when they meet and mingle, condensation of vapor would be the result. But as it is known from experiment, that if the air, at the temperature of 32° at the surface of the earth, should rise in the atmosphere to where the air would be expanded into double the volume, it would be colder by about 90°, and if the air should sink from the surface of the atmosphere to where the barometer stands 15 inches, it would rise in temperature more than 90°, it follows that when these two masses of air met, the upper mass would be the warmest, and its capacity for vapor being thus very much increased, its tendency, on mingling with the lower air, would be to prevent the formation of cloud, and if a cloud was formed at all, it would be by the cold of the lower portion.

But besides the impossibility of finding any cause for this whirlwind in mid-air, it is contradicted by the whole appearance of the cloud connected with a tempest, whenever an observer is so situated as to see the whole cloud. For the circumference of the cloud always appears almost motionless, while the tempest is raging below with the greatest fury. And the upper part of the cloud, instead of rolling inwards, as it would do if there was a motion in the upper air downwards, seems to spread itself outwards, especially towards the N. E., something in the form of a mushroom, and finally into thin cirrus at the end of the rain.

On the other hand, if the air did really move inwards at the circumference of the storm, all the phenomena attending it may easily be explained on well known philosophical principles.

It could not move inwards at the circumference below, without moving upwards in the middle; it could not move upwards in the middle, without becoming colder, something more than 1° for every hundred yards of elevation, until it reached the point where condensation of the vapor would commence; above which it would cool only about half that quantity, the other half being made up by the latent caloric given out by the condensing vapor — the latent caloric cannot be given out without expanding the air in contact with it about 7000 cubic feet for every cubic foot of water generated, and thus producing a highly diminished specific gravity of the air in a rapidly forming cloud. This diminished specific gravity will cause the barometer to fall at the surface of the earth below, and the air will run inwards and upwards with a velocity which, the fall of the barometer being given, may be calculated where the storm is very narrow, as in spouts, on the principle of spouting fluids. (118, note.)

This upward velocity, where the barometer falls one inch, is about 240 feet a second, and is quite sufficient to cause a condensation of vapor great enough to produce those cataracts of rain which sometimes fall in a short time over a very limited extent (section 8); and also to carry up large drops of rain above the region of perpetual congelation, and throw them off at the side of the ascending column, frozen into hail, sometimes 12 inches deep in 12 minutes. Even the shape of the tornado cloud, or water spout, is explained by the sinking of the barometer under the cloud ; for the expansion of the air under the cloud may be so great that the cold produced by that expansion may cause condensation of the vapor in the air below the cloud down to the very ground. I might go on to mention every phenomena connected with storms, and show that they are all explained by the evolution of caloric in condensation of vapor; but this is not my present object.

157. After making one or two other remarks, I shall proceed to give the particulars from which all these generalizations have been deduced. Mr. Redfield says, Dr. Mitchell has recorded, as the result of the observation of laboring people in New York, that when a haze or cirrus, which, appearing at sunset, indicates the approach of a storm, is seen over Staten Island at S. W., or more southerly, the storm of the succeeding day will blow from the *north east;* but if it appears over the Jersey shore of the Hudson, from W. S. W. to N. W., then the storm is expected to blow from the S. E. From this it would appear that the wind blows towards the cloud of an approaching storm.

What is the shape of storms generally? or do they greatly differ in shape?

Dr. Thomas, of Richmond, N. C., told me that he has frequently seen storms of great length from N. E. to S. W., and very narrow from S. E. to N. W., make their appearance to the N. W. of where he lived, and approach him, coming up, side foremost, against a S. E. wind, pass over in half an hour, with the wind suddenly changing round to N. W. If this should be found to be the shape of those storms at sea, which Mr. Redfield says so often set in from S. E. and change round to N. W., it would be in harmony with the centripetal theory. But I forbear to hypothesise — the day is not far distant when the public will see the importance of having *facts* on this subject ascertained by a system of wide spread simultaneous observations.

Facts collected by Mr. Redfield, taken from Silliman's Journal, vol. XX.

158. "The earliest supposed trace of this hurricane which has been obtained, is from off Turk's Island, in the West Indies, where it appeared on the 1st of September, two days previous to its reaching our coast. It was felt there severely, but at what hour in the day we are not informed.

The next account we have is from lat. 23° 43′, where the storm was severe, September 1st, from S. E. to S. W. Whether these two accounts are considered as identifying the storm, or otherwise, will not, at this time, be deemed material.

Our next report is from lat. 32° 30′, lon. 77° west from Greenwich, on the night of September 2d; a hurricane for three hours.

At 3, A. M., on the 3d of September, a severe gale was experienced thirty miles outside of the American coast, off Wilmington, N. C.

At Wilmington there was no gale.

At Ocracock bar, N. C., at day light on the morning of the 3d, a severe gale from E. S. E.

At Edenton, N. C., the gale was at N. E.

Off Roanoke, on the morning of the 3d, a dreadful gale at E., then S. W. and N. W.

A vessel from Charleston, S. C., two days previous to arriving in the Chesapeake, experienced the gale at 4, A. M., on the 3d, from S. E. to W. S. W.

A vessel from Bermuda experienced the gale from the westward, on the inner edge of the Gulf stream.

Another vessel, from Charleston, did not experience the gale.

In lat. 37° 30′, on the inner edge of the Gulf stream, gale from the westward, with squalls.

On James River, Va., the gale was severe from N. W.

At Norfolk, Va., the gale raged, on the 3d, for five hours, from N. N. E. to N. N. W., and terminated at the latter point; greatest violence from 10, A. M., to 1, P. M.

At sea, forty miles N. of Cape Henry, severe from S. E., changing to N. W.

Off Chincoteague, coast of Maryland, on the 3d, gale from S. E.

At Snowhill, Md., gale commenced at 11, A. M.

In lat. 38° 30′, lon. 74° 30′, gale S. by E.

Gale reported as slight in the Gulf stream.

A ship from Boston, bound to Norfolk, experienced nothing of the gale. On the 3d, was in lat. 40° 19′; weather foggy, and light winds from S. E.

At Morris River, Del., the gale was from E. S. E.

No hurricane was felt at Baltimore.

At Cape Henlopen, Del., the gale, or hurricane, commenced at half past 11, A. M., from E. S. E., shifted in twenty minutes to E. N. E., and blew very heavy for nearly an hour. A calm of half an hour succeeded, and the wind then shifted to the W. N. W., and blew, if possible, with still greater violence.

At Cape May, N. J., commenced at N. E., at 2, P. M., and veered to S. E., and blew with violence. After abating fifteen minutes, it again blew with increased violence for two hours, and then abated. The sun set clear, with pleasant weather, at which time not a cloud was to be seen in the western horizon.

At Bombay Hook, near the mouth of the Delaware river, the gale blew from N. N. E. to W. N. W.

At sea, forty miles N. E. of Cape May, the gale was at S. E., and lasted eight hours.

t Philadelphia, the storm commenced at 1, P. M., on the 3d, from N. to E., and raged with great violence from N. E. to N. W., during the greater part of the afternoon.

At Trenton, N. J., the gale commenced at 3, P. M., with the wind from N. E.

In lat. 39° 20′, long. 73° 30′, the gale blew from E. S. E. to S. S. E., and continued eight hours.

At New York, the gale was from N. E. to E., and commenced blowing with violence at 5, P. M., continued with great fury for three hours, and then changed to W. More damage was sustained in two hours than was ever before witnessed in the city, the wind increasing during the afternoon, and at sunset was a hurricane. At the time of low water, the wharves were overflowed, the water having risen thirteen feet in one hour. Previous to the setting in of the gale, the wind was from S. to S. E., but changed to the N. E. at the commencement of the storm, and blew with great fury till evening, and then shifted to the westward.

At the quarantine, Staten Island, the wind was reported as E. S. E. Other accounts fix it at E.

At Bridgeport, Conn., the gale commenced violently at S. E., at 6, P. M., and continued till 9, P. M., then shifted to N. W., and blew till nearly 11, P. M.

At New London, the gale was felt from 7, P. M. to 12, at night.

On the coast of Rhode Island, between Point Judith and Watch Hill, gale from the S.

At Middletown, Conn., violent from S. E. for five hours.

At Hartford, commenced heavy from S. E. at 7, P. M.

At Springfield, Mass., violent from 9 till 12, P. M., then changed to the westward.

At Northampton, from S. E. on the same evening.

At Worcester, Mass., in the night between 3d and 4th of September.

At Boston, the gale commenced at 10, P. M., but does not appear to have been severe.

At the time the storm was raging with its greatest fury at

New York, the citizens of Boston were witnessing the ascent of a balloon, and the aeronaut met with little or no wind. The general course of this storm, northward of Cape Hatteras, appears to have been from S. S. W. to N. N. E., and of its further progress we are uninformed.

It appears, from the foregoing statement of facts, that this storm, previous to its reaching Long Island, extended but a moderate distance inland, and that its influence seaward from the east, was almost equally limited; that between these boundaries it maintained a regular progress along the coast from a great distance towards the south, and probably even in the neighborhood of the West India Islands; that this progress, though slower in the lower latitudes, was, after reaching the American coast, at a rate not greatly differing from thirty geographical, or nautical, miles per hour, which is presumed to have been nearly the velocity of the direct southerly current prevailing in the atmosphere at that time, at a medium height from the surface at this rate of progression, appears to have governed the duration and termination of the storm at each place over which it passed — that on the western margin, or verge, of the storm, or at those places most distant from the sea, the wind was north easterly or northerly, while on the opposite verge, at sea, the wind was southerly and westerly; — that along the central portion of the tract, the storm was violent from the south eastern quarter, *changing suddenly to an opposite direction*;[1] — and that there was previously and subsequently no prevalence of an easterly wind, nor was there any other apparent cause for a direct movement of the atmosphere from that quarter; all the existing tendencies being in another direction. The centre of the storm, or hurricane,

[1] It is remarkable that not one instance is to be found in this storm in which the wind changed suddenly round to N. W., where it set in from S. E. (See p. 211, 4th.)

appears to have been generally outside the coast, till, reaching Long Island, it crossed the same, and entered upon the State of Connecticut. It seems also to have passed westward of New Haven, and to have entered the valley of Connecticut river near Middletown, and after partially following that valley for some distance, and crossing the State of Massachusetts, the storm must have disappeared towards the eastern coast, and its further progress does not appear to have been reported. The general analogy or correspondence of the forgoing facts to the known phenomena of whirlwinds and tornadoes will, it is believed, be sufficiently evident, at least so far as the difference in the magnitude and other circumstances of these rotative masses will permit of the resemblance."

Facts collected by Mr. Espy, taken from the newspapers of the time.

159. *Aurora, Sept.* 10, 1821.—*Norfolk, Sept. 4th.*—Among the rest of our misfortunes, we are grieved to state that our town was visited on *yesterday* by a storm or tornado, &c. The morning was dark and gloomy; at 6 o'clock rain began to fall in torrents. At 10 it abated a few minutes, and then came again with increased violence, and the wind commenced blowing a heavy gale from the N. E., and continued to increase to an alarming height. From 11½ to 12½ o'clock, the fury was such as to threaten a general demolition, &c. About 12, the wind shifted to N. W., and continued its fury until half an hour after, and the storm began to subside. At 4 o'clock, the wind changed to S. W., and the weather became calm.

New York, Sept. 4th.—From Saturday (the 1st) till 4 o'clock, we were visited with repeated showers, accompanied with thunder and lightning. The wind veered and shifted to almost every point.

National Intelligencer, Sept. 8th. — At New Haven, the gale commenced 6, P. M., and from 8 to 10 increased to a violent tornado.

National Intelligencer, Sept. 10th. — Steamboat Norfolk left Baltimore on the 3d, at 9½, A. M., wind at the time light N. W., with rain. At 2, P. M., off Poplar Island, about half way from Baltimore to the mouth of the Potomac, commenced a most tremendous gale from N., with heavy rain, which continued to increase in violence till 4, when it moderated, and at 12 at night, off the mouth of the Potomac, took in tow the ship Repeater, which had left Annapolis at 3, A. M., and at 2, P. M., near Point Look Out, was obliged to cut away all her rigging, the wind blowing a heavy gale from N. E.

National Intelligencer, Sept. 12th. — Captain Crabtree, twenty-five leagues to the S. by E. of Cape Hatteras, says, that on the night of the 2d, a violent gale came on to blow from E. S. E., and began to abate at noon of the 3d. The Franklin Gazette, Philadelphia, says the wind at New York had been S. and S. E. most of the day, but between 4 and 5 it changed to N. E., and blew until near 7, with great violence. About that hour the wind abated, and soon after shifted to W. N. W.

Sept. 6th, same paper. — Steamboat Connecticut, at New Haven, had the wind first from E., but at 10½ o'clock it got round to S. *Same paper of Sept.* 7, at New Brunswick, tremendous storm from N. E., with torrents of rain in P. M.

National Gazette, Sept. 8th. — Capt. West, of the ship Tuscarora, got under weigh from New Castle at 7, A. M., wind N. E. About 10, came on to blow fresh, with very thick weather and much rain. At 11, came to anchor in Bombay Hook Roads. The wind and rain increased to a violent gale. About 3, began to drift. The wind commenced N. E., and the strongest was from N. At 6 it veered to N. W., moderated and cleared up.

Same paper, Sept. 10th. — Schooner Gen. Green, between Capes Sable and Ann, had a strong breeze, but no gale, though every vessel in Quarantine Roads (Boston) dragged anchor.

Freemen's Journal, Sept. 8th. — Schooner Swan, in lat. 39° 20′, (Evening Post, of 7th, says lat. 36° 20′) long. 73° 30′, encountered the hurricane, which continued for eight hours, E. S. E. to S. S. E. Also, sloop Regulator, in lat. 38° 30′, long. 74° 30′, experienced a tremendous gale from S. by E., and lay to ten hours. At Huntingdon, L. I., at 7, P. M., we were visited by a most tremendous gale of wind from the N. E.

Freeman's Journal, Sept. 11. Ship Repeater, near Point Look-Out, had wind from N. E. From 12 to 2 a most violent gale, (Delaware Bay).

Freeman's Journal, Sept. 11. Schooner Rising States, two days from Charleston towards New York, had a violent gale which lasted six hours, from S. E. to W. S. W.

New York Evening Post, Sept. 4. The gale at Jersey City was from N. E., accompanied with hail and rain, which fell in torrents.

Sept. 5. At Quarantine, the commencement of the gale was E. S. E.

Sept. 10. Schooner Polly and Sophia, forty miles N. E. of the Capes of the Delaware, experienced a most tremendous gale from the S. E., which lasted eight hours.

American Daily Advertiser, Sept. 6. From New York of Sept. 4. About 4½, P. M., yesterday, the wind came out from about E., with all the fury of a hurricane, and continued till about 8½, P. M.

Sept. 7. From a Norfolk paper of the 4th. Yesterday, between the hours of 10, A. M. and 1, P. M., our town was visited by a hurricane, accompanied by torrents of rain, commencing from N. E. and terminating at N. N. W.

Also, from the Bridgeport, (Conn.) Farmer. After two or three days of dull cloudy weather, with frequent heavy showers, we were on Monday evening (3d) visited by the most dreadful hurricane which has been experienced for many years. The wind commenced blowing hard from S. E. about 6, P. M., accompanied with rain, and continued to increase in violence till about 9, P. M., when the tempest raged with a degree of fury the most awful and destructive. The storm continued with unabated force till near 11, P. M., when the wind hauled round to S. W., and gradually subsided.

Also, in a letter from New Haven, by a gentleman who left there at 6, P. M., in steamboat Connecticut: "As we approached the light house at the harbor's mouth, the wind, which had been blowing very hard, became violent, and we anchored in the Cove, between the Fork and light house. The gale kept increasing, and our vessel dragged her anchors, in spite of a great scope of cable and the assistance of the engine. Suddenly the wind shifted to S. W., and blew a perfect hurricane.

Also, from New York American, Sept. 3, 1821. In the early part of the day, and at intervals till late in the afternoon, heavy showers, with steady breezes from the S. E. From 5 to 6, P. M., the wind and rain increasing, with every indication of a settled storm. From 6 to about 7½, P. M., the wind E. S. E., but varying to E. and E. N. E., accompanied with rain; blew with extreme violence. From 7½ to 8, P. M., the wind had much abated; it then veered round to the S. W., and the clouds were swept away with astonishing quickness. Bar. lowest at 7.30 — 29.34, having been in the morning at 6h. 30.13 inches.

Poulson, Sept. 10. Dennis's Creek. On the 3d inst. the wind came on to blow, about 2, from the eastward, and continued to increase until about 5, P. M. At about 5, the wind changed to the westward, still blowing very heavy (near Goshen Creek and Maurice River). Poulson, Sept. 5, at Philadelphia, a storm of rain commenced about 1, P. M., on the 3d, accompanied with high wind, which increased almost into a tornado in the afternoon. The wind was generally from N. to N. E. during its greatest fury, but varied occasionally to almost every point of the compass. . . . Much damage was done at the navy yard by the violence of the gale during its rage from the N. E. and N. W.

Poulson, Sept. 8. Mr. Guille ascended in his balloon at 4h. 45m., at Boston, and sailed towards the N. W. Sept. 10, on Monday night, 3d, a short but severe gale from the S. E. did considerable damage to the trees and fruit in that vicinity; and at Worcester, Mass., the gale commenced at 9, P. M., and increased till midnight; and at Middletown lasted five hours. And the New York Evening Post of Sept. 7, says that this gale at Middletown was from S. E., commencing about 9, P. M., and at Boston at 10, P. M. And the same paper says that the rains were very great at Baltimore and Annapolis.

National Gazette, Sept. 6. The gale of 3d September was almost a hurricane at Bombay Hook for about an hour, from N. E. to N. N. W.

Sept. 7, *at Cape May*, from 1, P. M. till half past 4, the wind blew a violent hurricane S. E. Hugh's large house had the piazza blown off.

Freeman's Journal, Sept. 11. At Annapolis, at 4, A. M., wind W. N. W. and rainy. At the mouth of the Patuxent, at 11½, gale increasing and inclining northward. At Point Look-Out, still inclining to N.E., and at 2, P. M., very violent N. E. At 6, P. M., the gale had abated.

Same paper, Sept. 12. About five miles below Reedy Island, at noon, the wind hauled to N. E. from the S. E., and hauled round to N. N. W., blowing a heavy gale. (Delaware Bay.)

Same paper, Sept. 15. Brig Panopea, seventy-five miles S. by E. from Cape Hatteras. It came on to blow a gale from E. S. E. on the night of the 2d. On the 3d, at noon, the gale began to abate. Also, the Atalanta, off Cape Hatteras, experienced a severe gale from S. E. At Ocracock, at daylight, wind E. S. E., blowing a gale; after hauling round to S. S. W., ceased between 10 and 11, A. M., both at Ocracock and Portsmouth.

NEW HAVEN.

Date. 1821.	Thermometer.			Barometer.			Rain.	Wind.		Weather.
	Sun rise.	2 P.M	10 PM	Sun rise.	2 P.M.	10 P.M.	inches.	Sun rise.	2 P. M.	
Sept. 1	70	82	73	30.02	30.03	30.02	.78	S.	S.	Cloudy, Broken R. Cloudy.
2	70	78	71	.02	29.97	29.97	.62	S.	S.	do. R. Cloudy R. do.
3	70	80	70	29.97	.92	.47	.72	S.	S. E.	do. R. do. do.
4	68	73	68	.90	.85	.81		S.		Broken do. do.
5	62	75	62	.73	.74	.76		W.	S. W.	Clear. Clear. Clear.

"On the evening of the 3d, between 7 and 12, P. M., the most violent storm of wind occurred that has happened since 1815." During the evening, Mr. Herrick thinks the wind was from S. E. to S.

These observations, made at New Haven, Connecticut, are furnished by Charles Rich, Esq., of that place.

NEW BEDFORD.

Extract from Mr. Samuel Rodman's Journal.

Day.	Thermometer.				Barometer.				Wind.			Weather.
	Sunrise.	2, P. M.	Sunset.	10, P. M.	Sunrise.	2, P. M.	Sunset.	10, P. M.	Morning.	Noon.	Evening.	
2	72	77	74	73	30.10	30.09	30.08	30.06	S. W.	S. W.	S. W.	
3	74	79	75	74	30.05	30.04	29.97	29.86	S. E	S.	S. E.	Very severe
4	67	70	70	70	29.92	29.90	29.87	29.85	S.	S.	S.	gale at night.

I will now add, that the reader will perceive, by a careful examination of these facts, that all the generalizations given above are fairly deduced; and that they all, when combined, form a most satisfactory demonstration of the theory advocated and developed in the preceding papers. Moreover, as the wind on the S. E. side of the storm had been blowing all day, before the storm came on, from the S. E., and on the N. W. side of the storm from the N. W., there appears no reason for the motion of the storm from the S. W., but the uppermost current of the atmosphere, which is known to be almost always moving in this direction.

Philadelphia, March 13, 1839.

Hurricane of the middle of August, 1837.

160. *St. Augustine, Aug.* 19, 1837. On Tuesday, the 15th August, we were visited by a third gale of wind, of equal severity with the two which preceded it, and which continued until the afternoon of Friday, 18th August, when it ceased. *American paper.*

A severe Gale at Turk's Island on the 15*th August.* From Lloyd's List. Narrative of Mr. Wilkinson, master of the Calypso, in the storm of the middle of August, 1837.

"On the 15th August, noon, the Calypso was, by observation, in lat. 26° 47′ N., and lon. 75° 5′ W.; the wind was from the eastward, about *east northeast;* she had royals and foretopmast studding sails set. Shortly after, we got a heavy swell from the north eastward, and the wind gradually freshened till 9 o'clock, when only the double reefed topsails, reefed foresail and mizzen could be carried. During the night the wind increased, and at 10 next morning, the wind about N. E., the lee rail under water, and the masts bending like canes; got a tarpaulin on the main rigging, and took the maintopsail in; the ship laboring much, obliged main and bilge pumps to be kept constantly going. At 6, P. M., the wind *north west,* I should think that the latitude would be about 27°, and longitude 77°.

"At midnight, the wind was *west,* when a sea took the quarter boat away. At day dawn, or rather, I should have said, the time when the day would have dawned, the wind was *south west*, and a sea stove the fore scuttle; all attempts to stop this leak were useless, for when the ship pitched, the scuttle was considerably under water. The wind, from about noon of the 16th, till about 10, or noon, of the 17th, blew with nearly the same violence. There was no lull; neither did it fly from one point of the compass to the other, but backed from *east north east* to *south west*, and then died away gradually.

"On Sunday, the 20th, while beating off Rum Key, the wind was variable and squally. On Monday, in lat. 24° 40′, lon. 74° 45′, we had fine steady winds from the eastward."

The Mary, Sharp, from New Orleans to Barbadoes, was abandoned on the 5th September, lat. 32°, lon. 80, having been dismasted and thrown on her beam ends, with six feet water in her hold, in a gale on the 16th August, in lat. 27° 30′, lon. 73° 53′.

"The brig Yankee, on the 16th August, in lat. 24° 30′, lon. 70° 30′, experienced a severe gale of wind from the N. E. to S. W., which lasted till the 20th." *N. Y. General Advertiser.*

The Rosebud, Dick, from Havana to London, was capsized and dismasted on the 18th August, in lat. 34° lon. 74°.

Wilmington newspaper, Aug. 25. "On the afternoon of Friday the 18th, the wind shifted to the *north east*, and rain began to pour heavily. Before midnight the storm increased, threatening ruin, &c. The tide rose six feet higher than usual."

The Westchester, from Havana, experienced a heavy gale from the *north east* on the 18th, and on the 20th, in lat. 32°, lon. 74°.

The Maria, from Honduras to London, on the 20th August, in lat. 33°, lon. 74°, capsized.

Log of Ship Sophia. On afternoon of 15th, wind E. N. E., steady and moderate, with a heavy lowering; at 4, P. M., in top gallant sails and gaff topsail; at midnight, do. weather; morning, breeze freshening; at noon, strong breeze, with a very stormy appearance, the swell evidently increasing; latitude observed, 31° 37′, lon. per chronometer, 74° 54′ 30″, barometer at fair.

Afternoon of 16th, wind N. E. by E., steady; the sky loaded to the eastward with heavy, sluggish clouds, and apparently no distance over head. At 3, P. M., down royal yards; at 6, breeze freshening; at midnight, strong gale, with high cross sea, the mercury much agitated and inclined to fall. At 6, A. M., of the 17th, set the foresail again, at noon very hazy round the horizon, with the appearance over head as yesterday; lat. 33° 3′, lon. 75° 9′; barometer fallen to change.

Afternoon, wind E. N. E., with the same wild appearance, and every indication of a dangerous change of weather; at 3, P. M., wore ship to southward, barometer still falling, wind E., gale increasing. At daylight of 18th, in fore and maintop sails, &c. At noon, heavy gale of wind E. S. E., the sky as if closing around us, and having a most dismal appearance; barometer from stormy to change.

Afternoon, heavy gale, with violent squalls and rain, wind S. S. E. At 6, P. M., blowing a hurricane; wind S. S. E. Same weather continued till midnight of the 19th. On the morning of the 20th, the wind backed gradually to the northward, with no abatement, and at noon the wind was N. N. W., but not the least abatement — no observation; barometer as yesterday. At 1, P. M., of 20th, wind at N. W. At 6, more violent, if possible. At 8, inclined to moderate, and the barometer to rise. At midnight, still dark and gloomy — mercury rising fast. At 10, A. M., of 21st, a fine steady breeze from the westward. At noon, lat. 34° 38′, lon. 74° 20′, having made, since last observation, against wind and sea, 95 miles of northing, and 49 of longitude; barometer at fair.

Narrative of Mr. Macqueen, master of the Ship Rawlins, from Jamaica to London.

Latitude — Commencement	N. 30° 30′.	
Termination	30 40.	
Longitude — Commencement	W. 77 40.	
Termination	77 18.	

Wind commenced on the 16th, at N. E. by E. blowing strong from that quarter about twelve hours, then suddenly to N., continuing with unabated vigor till midnight of the 17th; in an instant a perfect calm ensued for one hour, then, quick as thought, the hurricane sprung up with tremendous force from the *south west, not again shifting from that point.* No swell whatever preceded the convulsion. The barometer gave every notice of the coming gale for many hours previous. Two days antecedent, the weather was beautifully serene, but oppressively hot, with light shifting airs; the barometer at that time standing at "set fair;" during the gale so low as almost to be invisible in the tube above the frame work of the instrument. The force subsided at midnight, August 18th. the sea tremendous, and rising in every direction; from the force of the wind no tops to the waves, being dispersed in one sheet of white foam; the decks tenanted by many sea birds in an exhausted state, seeking shelter in the vessel; impossible to discern any thing, even during the day, at fifty yards distance; the wind, representing numberless voices, elevated to the shrillest tone of screaming; but few flashes of lightning, and those in the S. W. On the 19th, wind and sea much abated. A dismal appearance to the N. W.

Narrative of Mr. Turner, master of the ship West Indian, from Jamaica to London. — At noon of the 14th, lat. 28° 28′, lon. 79° 45′, barometer 30.1 inches. At 5 P. M. the weather put on an unsettled appearance, and a strong swell began to set in from the E. N. E., which continued to increase, as did also the wind from the N. E.; the next morning the sky was more settled.

At noon of the 15th, barometer 30.00, lat. 31° 49′, lon. 77° 59′. The heat of the water eight or ten degrees warmer than the air, which became equal about midnight. Fresh winds, variable from E. N. E. to N. E., gradually increasing on the morning of the 16th. At noon, no observation, lat., by account, 31° 23′, lon. 77°13′; bar. 30.00, blowing fresh, wind E. N. E.

At daylight on the 16th, the sky had put on a very threatening aspect; ship's head to the E. S. E., with a tremendous sea from that direction; wind and sea continued to increase all day, with rain; barometer not falling, till five, P. M., when it went down 6‴ in. At three o'clock, A. M. of the 17th, the hurricane commenced, and about noon at its meridian, wind E. N. E. Ship lying to; lat., by account, 31° 8′, lon. 77° 56′, barometer 29° 1′. The wind drawing more easterly. At six, P. M., wind *east south east*, and inclining to the southward; just after midnight it fell nearly calm. At two, A. M., of the 18th, came out in an instant, with all its former violence, from the S. W.

At noon, by account, lat. 31° 21′, lon. 78° 6′, barometer 28° 8′; hurricane still continuing with all its former violence; at midnight it moderated a little, wind veering to the westward all the time. At 4, A. M., of the 19th, the wind about W.; got the ship before the wind under close reefed topsails, and scudded before the gale. At noon of 19th, lat., by account, 31° 42′, lon. 77° 14′, barometer 29.30; continued to run before the gale all these 24 hours, the wind getting round to N. W.

At noon on the 20th, lat., by observation, 33° 32′, lon. 72° 13′. In four days ship has been set N. 52° E 130 miles. For some days after this, we had very unsettled weather, with a great deal of sea.

Log of Brig Mary.—On 16th, in lat. 31° 3′, lon. 77° 50′, thermometer, in shade, 82, water 82°, barometer 29.10, having fallen, from the 15th, six tenths of an inch. Wind E. S. E. At noon of the 17th, wind E. by N., and N. E. by E. Strong gales and heavy squalls, with a head sea from N. E., barometer 29.00. Thermometer 82°.

On the 18th, wind E. S. E.; increasing gales; every appearance of bad weather; bar. falling fast; laboring and straining; bar. 28° 70′. Ther. 80.° Water 82°.

On 19th, wind S. E., gale increased to a perfect hurricane; barometer 28° 60′. On 20th, wind E. S. E., rising and falling very fast, and unsettled for the last 24 hours; barometer 28° 50°; thermometer, in shade, 74°; water 78°. On 21st, wind from S. E. to N. W.; barometer 28° 10′; a terrific appearance; thermometer, in air, 70°; water 76°; under bare poles; nothing can withstand the wind at present; hurricane continuing to rage more and more; at noon gale abating; barometer rising gradually; I could not leave the deck to note it, but it certainly must have been lower; noon 28° 40′; therm. 70; water 76. P. M., lat. 36° 12′, lon. 72° 11′. On 22d, wind S. W. to N. W.; made all sail that circumstances would permit; heavy rain, thunder and lightning; lat. 36° 22′ lon. 70° 6′; barom. 28.80.

Extract from the Log of the Barque Penelope, J. H. Grimes, Master, from Jamaica to London.—August 18th, P. M. Strong gales E. S. E. and cloudy; at four, P. M., ship laboring very much, and making a great deal of water; midnight, strong gales; at three, A. M, of 19th, wore ship to southward, wind E. S. E. At six, A. M., wore ship to northward; at ten, A. M. hard gales. At noon, lat., by account, 34° 56′, lon. 75° 2′ hard gales N. E., and heavy sea; at four P. M. gale increasing; at eight, P. M. tremendous gales. At two, A. M. of 20th, set main trysail, to keep ship to; in five minutes it blew away in tatters; wind from E. to S. E. At eight, A. M. wind moderated; at ten, more moderate; set close reefed fore topsail; wind E. S. E. to E.; noon, dark cloudy weather; wore ship to southward; noon, lat., by account, 35° 20′, lon. 75° 20′.

In P. M. of 20th, strong gales E. S. E. At four, P. M. wore ship to N. E.

At nine, A. M., (P. M. ?) gale increasing, and the wind having veered to N. N. W., came to a resolution of running before it, till the gale abated; at midnight it blew a perfect hurricane from N. N. W.; at ten, A. M. more moderate. At noon, lat. 34° 30′, lon. 72° 20′; at six, P. M. of 21st, wind hauled to S. W. Made up my mind to gain a port to the northward of Cape Hatteras; latter part of the hurricane from N. N. W.

Extract from the Log of the Barque West Indian, Simpson, Master, from Jamaica to London.—Aug. 20, at noon, lat. 37° lon. 64°, barometer falling, wind variable these twenty-four hours, from S. W. to E. On 21st, wind variable from S. to S. E., increasing gales and heavy sea from N. E.; at noon hard gales and hazy, barometer down below rain; lat., by account, 38° 23′, lon. 62° 40′. At six, P. M., hard gales, wind S. At ten, blowing quite a hurricane; we are now involved in a white smoke or fog, and the water as white as a sheet. At midnight nearly calm. At one, A. M., the wind came away from about W., and, if possible, blew harder than ever. At six, A. M., it is blowing a hurricane, and continued till two, P. M., when it moderated. Lat., by account, 39° 9′, lon. 61° 34′. I have always met with more hurricanes and tempestuous weather in the Gulf stream than I have found either to the northward or southward, and I cannot account for it.

Extract from the Log of the Ship Ida, Tilley, Master.—Tuesday, Aug. 15. Light breezes E. N. E., and cloudy weather; at noon, light breezes and fine; lat. 27° 31′, lon. 79° 36′, ther. 85, barom. 30.10. At midnight, wind E. N. E. At noon on 16th, fresh breezes and squally weather; lat. 29° 54′, lon. 79° 39′, ther. 80, barom. 29.80. P. M., strong breezes; at 3, wind N. N. E. At midnight, strong breezes and cloudy, with a swell from the eastward; barom. 29.20. On 17th, fresh gales, increasing till noon, when it blew a hurricane; barom. 29, wind N. E. At midnight, blowing a tremendous hurricane, with rain and heavy mountainous sea; barom. 28.50. On 18th, A. M., blowing a most tremendous hurricane, wind veering from N. E. to S. W. within the last twelve hours. At midnight of 18th, found we had run out of the hurricane, but it still blew a heavy gale. On A. M., of 19th, wind W. with strong gales and high sea. On 19th, wind W. all day, and also on the 20th. On 21st, S. W. all day, with strong breezes and squally; lat. 32° 7′, lon. 7° 30′, (76° 30′). On 22d, wind S. W., light breezes and fine weather; at 4, A. M., strong breezes and squally weather; made a signal of distress to the Citizen, and abandoned the Ida in lat. 33° 14′, lon. 75° 19′.

Extract from the Log of the Ship Westbrook, J. Freeman, Commander, from Jamaica to London. — At 1, P. M., on 15th, light baffling winds; at 7, P. M., increasing wind and looking squally; midnight, wind E. S. E., steady and clear; noon, lat. 32° 20′, lon. 76° 43′; wind variable. At 1, P. M., of 16th, wind N. E.; fresh; clear; at 8, P. M., very heavy appearance in the S., with a good deal of lightning; at 7, A. M., of the 17th, strong gales and a very heavy sea; noon, strong gales and very heavy squalls, with rain; lat. 32° 47′, lon. 76° 14′. At 1, P. M., wind E. by N., strong gales and hard squalls; midnight, do.; noon, of 18th, blowing strong and no appearance of change; wind E. from 5, A. M. At 1, P. M., wind S. E.; strong gales and a heavy sea. At midnight, came on to blow a complete hurricane; noon, no appearance of change. Wind at S. E., until 11, A. M., of 20th, when it veered to N. N. W. Throughout this twenty-four hours, a terrific hurricane and heavy rain. At 4, A. M., of the 21st, more moderate, and at noon, lat. 34° 58′, lon. 73° 32′; wind W. N. W.

Extract from Captain Herbert's Journal of the French Brig Yolof, from Havana to Havre. — Winds variable and weak from the 12th till the 16th, when we were in lat. 32° 14′, lon. 76° 25′ west of Greenwich. Then the wind began to blow from the E. N. E., increasing in force till the 17th, when it became a most frightful tempest, continuing, without intermission, till the 18th. On the 18th, from 8, A. M., till noon, great wind and rain. At 8, P. M., calm. Set two sails; but they were hardly set when the wind burst from the W. N. W. like a clap of thunder, and continued frightful all night and next day. On 20th, at 10, A. M., began to clear, and on 21st, fine weather, with slight breeze from S. W. On 20th, in lat. 32° 0′.

Narrative of Mr. Griffth, Master of the Ship Duke of Manchester. — At noon, on the 15th, light airs, and close, oppressive weather. From 4 till midnight, wind variable from N. E. to S. by E. On 16th, A. M., light variable winds, and a cloudy, confused sky.

At 8, A. M., a fresh breeze from the N., and hazy weather; a swell from the eastward. Noon, increasing breeze and cloudy; lat. 32° 39′, lon. 77° 30′. P. M., increasing breeze, wind veering from N. E. by E. to E. by N. At 5, fresh gale; at midnight, fresh gales and hazy; 17th, commences with strong gales and squally, with rain. Daybreak, heavy gales and tremendous sea. Noon, blowing a violent gale, with dangerous cross sea; lat. 31° 59′, lon. 77° 2′.

At 1, P. M., blowing a hurricane. A most extraordinary phenomenon presented itself to *windward*, almost in an instant, resembling a solid, black, perpendicular wall, about 15° or 20° above the horizon, and disappeared almost in a moment; then, in the same time, made its reappearance, and in five seconds was broken, and spread as far as the eye could see; from this time to midnight, blowing a most violent hurricane; much thunder and lightning, the thunder hardly heard, although we were struck with the electric fluid; wind continued E. to E. N. E. till noon of the 18th, with equal violence. In the afternoon it changed to S. W., a little more moderate, but continued violent with heavy gales till midnight of the 20th; wind W. a few hours in the afternoon of 19th, and then S. W. from 6, P. M., and on the 20th, W. S. W. all day, and also 21st. On the 19th, lat. 33° 7′. lon. 75° 37′; on the 20th, lat. 33° 47′ lon. 74° 52′.

Extract from the Log of the Ship Castries, from St. Lucia to Liverpool, M. Mondel, Commander. — At noon, 24th, lat. 34° 56′, lon. 57° 45′, strong winds E. by S., and cloudy. At 3, P. M., increasing gales. At 6, E. by N., blowing a hard gale with heavy rain. At 10, N. E., and at 11, blowing a hurricane. At 12, N. N. E., and at 2 in the morning of the 25th, wind N., at 4, W. N. W., and at 6, N. W., and so it continued till the 26th, clearing at 10, A. M., with strong breezes. At noon, of the 25th, lat. 35° 37′, lon. 57° 42′.

Note. — We had a sudden lull at 4, P. M., of the 24th, whilst reefing topsails.

The Victoria was upset and dismasted on the 24th of August, in lat. 33°, lon. 58°.

The barque Clydesdale, on the 24th August, encountered a very severe hurricane, in lat. 32° 30′, lon. 59° 30′. On the 23d, about noon, came on to blow fresh breezes from E. S. E. At midnight, atmosphere dark and wind S. E. At noon, of 24th, blew a complete hurricane, and at midnight gale moderated.

To these logs, which are extracted from Col. Reid, I am enabled to add a few particulars from the newspapers.

From the United States Gazette, of 28th Aug., 1837. — Brig Cicero, on 18th, in lat. 32° 20′, lon. 76° 40′, was struck with a hurricane from the N. E., shifting to N. W. and round to S. W. in 24 hours, and was hove on her beam ends.

Same paper, of 29th. — Severe gales at Washington, N. C., commencing on 18th, and continuing till Sunday evening, 20th. Five or six vessels driven on shore and wrecked.

Same paper, of 30th. — Delaware, on 17th, lat. 31° 30′, lon. 76° 20′, had a severe gale E. S. E., and then W., which continued till 20th.

Same paper, of 31st. — On the 19th and 20th, barque Penelope, in lat. 33° and 34°, lon. 72°, experienced a severe hurricane.

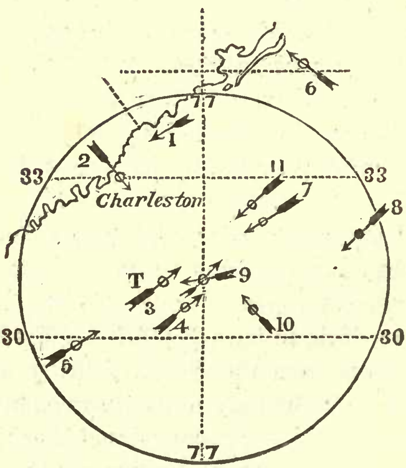
From the National Gazette, of 22d. — At the Delaware Breakwater, on the 20th, the wind N. E. at 7½, P. M., blowing heavy, with rain. At 10, A. M., of 21st, wind hauled to N. W.

From the Commercial Herald, of 28th. — The barque King Philip, on 18th, in lat. 31° 12′, lon. 78° 16′; had a gale from N. N. E. to W. N. W.

Same paper, of 29th. — Brig Oglethorpe, on the 18th of Aug., lat. 32° 29′, lon. 78° 55′; had a violent gale from N. W.

Great rains occurred in the western parts of Pennsylvania, on the 15th, and on the morning of the 16th, in the eastern parts. At Alexandria, D. C., wind S. on 18th.

Position of Storm at Noon, on the 18th of August, 1837.



EXPLANATION OF ENGRAVING.

1. Wind at Wilmington, on P. M., of 18th.
2. Oglethorp on 18th.
3. West Indian, all 18th, from 2, A. M.
4. Rawlins all 18th, from 2, A. M.
5. Ida, all day of 18th.
6. Penelope on P. M., of 18th.
7. Yolof till 8, P. M., of 18th.
8. Westchester on 18th.
9. Duke of Manchester till P. M., of 18th.
10. Delaware on 17th, and probably on 18th, changing round to westward on 20th.
11. Cicero on 18th.

I have culled out of this storm, that portion of time in which I find the greatest number of simultaneous observations, and I have exhibited on the annexed wood cut, the localities of all the ships within the boundaries of the storm, whose latitudes and longitudes could be ascertained with any degree of certainty, with arrows, exhibiting the course of the wind. The time is noon of the 18th of August, 1837. At this time, the Duke of Manchester was only a few miles N. E. of the centre of this storm, for some time in the afternoon, the centre of the storm passed nearly over her, when the wind changed pretty suddenly S. W. At this time, and for some seven or eight hours both before and after, all those ships which were laboring in the most violent part of the storm, had the wind blowing towards a central space of no great magnitude. This settles the question of a violent centripetal motion of the wind in this storm, in conformity with the five previously examined, and also with the twelve investigated by the Joint Committee of the American Philosophical Society and Franklin Institute, and with not less than fourteen land spouts which have already been examined, in all of which the trees were thrown with their tops inwards — and when any are thrown across each other, those which are underneath, are uniformly found to be thrown inwards and backwards, and those on the top, to be thrown inwards and forwards, just as they should be, if the wind blows inwards. Whereas, if the wind is centrifugal, many of the trees should have the tops thrown outwards on both sides of the path. Let the reader cast his eye on the chart, and he will perceive, in the borders of the storm, some anomalies worth his particular attention. If I have really discovered a true law of nature in these storms, these apparent anomalies will be found to confirm the law in a wonderful manner. Just as the moon's anomalies, when understood, were found to harmonize, in a most beautiful manner, with the law of gravitation. The anomalous arrows in this storm, are the Penelope and Wilmington on the N., which seem to favor the idea of a rotation of the air from right to left, and the Westchester on the east, which seems to indicate a rotation from left to right. This is in conformity with phenomena accompanying storms previously investigated by the Committee, (see article 100, also 116, Rationale) and it is in exact conformity with what ought to take place, if the wind does blow inwards towards the centre of the storm; as will appear from the following considerations. When the air rises in the centre of the storm, and expands by the evolution of the caloric of elasticity given out in the formation of cloud, upwards of six thousand cubic feet for every cubic foot of water generated in the cloud, as explained before, it must spread out in an annulus all round the borders of the storm, and cause the barometer to rise, in that annulus, above the mean, just as it did in this storm to the Rawlins, the Sophia, and West Indian, (Turner) as the storm was approaching their vessels, and as it is now known to do in all our great N. E. storms that come from the S. W. If a storm should spring up in our neighborhood, that is, commence in our vicinity, and not come upon us from a distance, such a rise of the barometer could not take place. Now this rise above the mean will evidently take place in front of the storm, because the upper current of air is moving in that direction, and of course the great body of the up-moving column of air in the middle parts of the storm will be pressed by the upper current in that direction. And it is manifest, that beyond the annulus where the barometer stands above the mean, the air will blow outwards from the storm, and within the annulus, it will blow inwards. But as in front of the storm, there is one point of the annulus where the barometer stands higher than in any other, the wind will tend in all directions from that point, and of course it will cause the wind, in the very borders of the storm, to appear to rotate both ways.

As the air must necessarily come downwards in the annulus where the barometer stands above the mean, "set fair," for instance, as it did with the Rawlins, we would expect the weather to be without a cloud, and very hot, as it was. Indeed, it would be easy to show, that if the air in the annulus were to come down from a height of four miles, it would be about 45° hotter than it was when it left the surface of the sea in the centre of the storm to go up, for it would bring down with it the caloric of elasticity evolved, as it went up, by the condensing vapor, and the quantity evolved in going up a given height is known if the dew point is given. But the full explanation of this subject is reserved for another occasion.

The centre of the storm at the moment I have chosen, the noon of the 18th, was between 31° and 32° N. lat., and was at that time moving about N. E., for the centre passed over the Rawlins, and very near to the Yolof, about 150 miles to the N. E. of the Rawlins. In this part of its course, it travelled only about 8 miles an hour; for it passed over the Rawlins at half after 12, in the morning of the 18th, and did not reach the Yolof till 8, P. M., of the same day.

If this storm was round on the 18th, of which we have no proof to the contrary, there is strong reason to believe it did not long continue round. For on the 21st, it reached from the Westbrook to the West Indian, (Simpson) about 700 miles; so that unless it widened out in like proportion in the other direction, its N. E. and S. W. diameter became greater than that from N. W. to S. E. If this was really the case, as it was in the storm of 1821, and if it moved towards the east, then all the phenomena would be easily explained, and the storm of the Wanstead, and the storm of the Clydesdale, Victoria, and Castries, would be one and the same storm.

This can be ascertained hereafter; for, in this case, it is probable that Bermuda experienced something of it on the

22d and 23d. If this meets the eye of any person acquainted with the fact, either one way or the other, let him communicate it to the world. New facts connected with any of the storms here investigated, would possess a very high degree of interest.

It appears from the logs of the Clydesdale and the Castries, that the storm passed over them about the same time, though the latter ship was near 200 miles to the N. E. of the former. Now this can only be accounted for on supposition that the centre of the storm is not a *point*, but a *line*, lying in the direction of N. E. and S. W., and moving side foremost, or obliquely. There is another circumstance which favors this idea, namely, the storm lasted a much shorter time with all the vessels on the 21st, 22d, 23d, and 24th, than on the 18th, though the storm was much greater in diameter on these days from N. E. to S. W. than it had been before, even with those ships near which the centre passed; for instance, the Columbus and the Delos. But it is useless to conjecture. The data are not yet sufficient to demonstrate whether there were two storms or one. I will merely add, that if the line joining the Clydesdale and the Castries should be prolonged, it would pass a little E. of the place where the Wanstead experienced a severe gale on the day before, lat. 43° 34′, lon. 54° 20′, which also favors the idea that these two storms were one and the same, with a long diameter from N. E. to S. W.

Raleigh's Typhoon of the 5th and 6th of August, 1835, *in the China Sea.*

161. As Mr. Redfield, of New York, has given a more full account of this storm than Col. Reid, I extract the following details from him.

" H. M. Brig Raleigh, August 1, 1835. — Working out of

Macao Roads. At noon, east end of Grand Ladrone, E. ½ S. Aug. 2d, at noon, S. E.; end of Formosa, N. 85, E. 340 miles; fine weather all day. Aug. 3d, at noon, S.; end of Formosa N. 82½, E. 252 miles. Fine weather all day. Aug. 4th, 10h. 20m. A. M. close reefed topsails and courses; 12h. 30m. P. M., barometer fell from noon $\frac{15}{100}$; took in mainsail and foresail; at 1h. 30m. got all snug; vessel going through the water between three and four knots; barometer 29.40, falling; at 7h. 30m. wind veered to N. N. E. and typhoon commenced; at 8, P. M. barometer 29.36, falling; 8h. 30m. typhoon increasing; 10, P. M., close reefed fore trysail and set it; typhoon veering to E. N. E. with a heavy sea; at midnight typhoon increasing; barom. 29.04, falling.

"Aug. 5th. 3, A. M., typhoon veering round to E. S. E., still increasing in violence; 6h. 30m. barom. 28.25; 8, A. M. typhoon increasing; 9h. 30m. A. M., if possible blowing heavier, *ship went over;* in this awful situation the ship lay for about 20 minutes; 9h. 50m. lower masts went by the board, and ship righted with 7 feet water in her hold; barometer did not fall lower; at noon typhoon moderated a little; at 6, P. M. typhoon more moderate, with a heavy sea; midnight, strong gusts of wind, with heavy sea from S." — Abridged from *Canton Register of March* 14, 1737.

At Macao, where the typhoon was experienced on the 5th and 6th, many houses were damaged; also many lives were lost in the inner harbor, and some vessels were driven on shore. The direction and changes of the wind at Macao are not stated; but we are favored with the following valuable table of the state of the barometer during the period of the storm.

h. m.	Barom.	h. m.	Barom.	h. m.	Barom.
“August 5th.		0 45 a. m.	28.30	6 45 a. m.	29.12
1 00 a. m.	29.47	1 20 “ (*lowest*)	28.05	7 45 “	29.20
2 30 p. m.	29.28	1 25 “	28.08	8 15 “	29.21
5 00 “	29.20	1 45 “	28.20	8 45 “	29.23
7 20 “	29.12	1 55 “	28.30	9 30 “	29.27
9 00 “	29.08	2 00 “	28.37	10 25 “	29.30
10 20 “	28.95	2 25 “	28.56	11 00 “	29.34
10 45 “	28.90	2 45 “	28.68	2 00 p. m.	29.42
11 05 “	28.85	3 10 “	28.75	and continued rising	
11 30 “	28.75	3 40 “	28.83	to 29.65, at which	
11 53 “	28.65	4 10 “	28.90	point it usually stands	
August 6th.		4 45 “	28.97	during fine weather.”	
0 15 a. m.	28.50	5 15 “	29.02	— *Canton Register*,	
0 30 “	28.40	6 00 “	29.08	*Aug.* 15.	

This table affords, in itself, good evidence of the passage of the centre of the vortex near to Macao.

At Canton, (60 miles N. of Macao,) the typhoon began on the evening of the 5th, after three or four days of very hot weather, with northerly winds, and continued throughout the night and the next day. Its violence was greatest about two o'clock on the morning of the 6th. The following is an account of the state of the barometer and winds at Canton:

August 4th.

9 a. m.	barom. 29.79	Wind	N. W.	Fine weather.
4 p. m.	“ 29.70	“	N. by W.	Moderate breeze.

August 5th.

9 a. m.	“ 29.62	Wind	N. and N. W.	Fair weather.
4 p. m.	“ 29.54	“		unsettled — rain and fresh breeze.
12 p. m.	“ 29.37	“	N.	blowing hard and in heavy gusts.

August 6th.

5 a. m.	"	29.34	Wind N. E.	blowing hard with heavy rain.
9 a. m.	"	29.51	" S. E.	do. do.
11 a. m.	"	29.58	" S. E.	blowing hard — moderating.
5 p. m.	"	29.70	" S. E.	do.
11 p. m.	"	29.85	" S. E.	do.

August 7th.

8 a. m.	"	29.94	Wind S. E.	Cloudy.

Compiled from the Canton Register.

On Wednesday, the 5th instant, a typhoon swept over the city of Canton. It began in the evening, and continued throughout the night and the next day, blowing its best about 2 o'clock in the morning.[1] The damage done by the typhoon at Canton is small, but not so at Kumsingmoon, Macao, and elsewhere on the coast. — *Canton Paper.*

Extract from a private letter from on board the ship Lady Hayes, which left Macao Roads a day or two before the storm, and returned to Kumsingmoon, after the gale.

"Early on the morning of the 5th, we observed indications of bad weather. At 10, A. M. the wind freshened a little from the same quarter it had been for the last 24 hours, viz. *north;* so we thought it best to turn her head back again to look for shelter, fancying ourselves to be about 35 miles off the land. We carried a press of sail until noon, when we found we had too great a distance to run before we could get into shelter, and expecting it would get so thick that we could not see our way; so we turned her head to sea, and clapped on as much sail as she could

[1] The reader will note particularly, that the wind at Canton was most violent just about the time the barometer was lowest at Macao, and that it was blowing towards Macao.

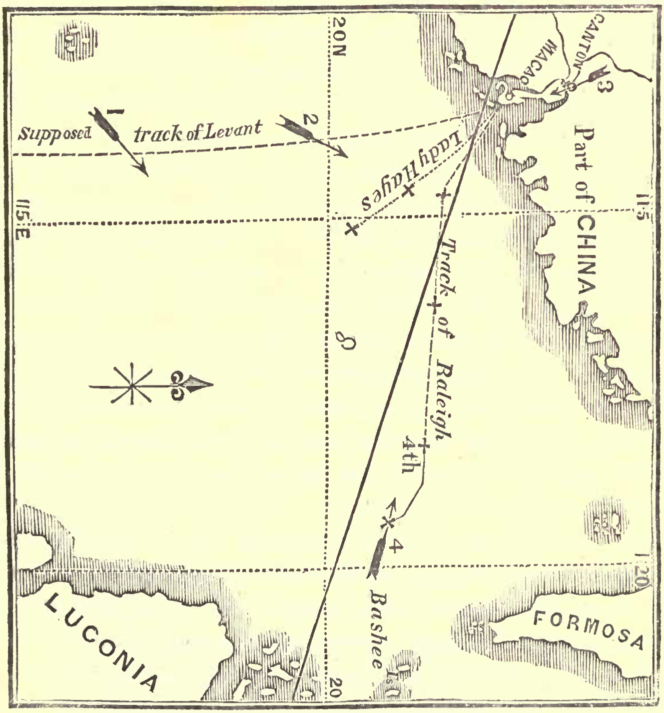
stagger under, *steering S. E. by E.* The wind being then at N., we were desirous of getting as far off the land as possible, expecting the wind round to the eastward, there being a most *tremendous swell* from that quarter. *At* 4, *P. M.* it was blowing in severe gusts, and we shipping a good deal of water, and the ship becoming unmanageable. About 8h. 30m. *the wind began to veer to the west*, but continued to blow as hard as ever, till midnight, when it *drew round to south*, and moderated a little. It continued to blow hard from that quarter until noon of the 6th, when it moderated fast, and we began bending other sails in room of those that were split. When the gale commenced, which we consider it did *at* 1, *P. M. on the 5th*, we were about 20 miles E. of the Lema; where we were when it ended it is hard to say, as we saw nothing till the morning of the 7th, when we made Mondego Island. We hardly think we could have had the gale so heavy as those inside; and what is most extraordinary, the wind with them *veered to the eastward round to south;* but with us it veered to the *westward* round to south. It was fortunate for us that it veered to the westward; for had it veered to eastward, we should most likely have been driven on shore among the islands, as we could not have been more than 50 miles off the land, at 8, P. M. on the 6th.—*Abridged from the Canton Register of August* 18*th.*

Log of the American Ship Levant, Capt. Dumaresq.

Courses.	Winds.	
N. N. E. Distance by log, 171 miles.	S. W. Breeze 6½ to 8 knots.	August 4th, 1835. [Nautical time.] Throughout these 24 hours fine breezes and clear, pleasant weather. All possible sail set. Current N. E. by N. 50 miles. Lat. by obs. 12° 55′ N. Long. by chr. 112° 13′ E.
N. by E. ½ E. N. by E. Distance by log, 190 miles.	S. W. Breeze 7 to 8½ knots.	Aug. 5th. Commences with fine breezes, and pleasant. All sail set and trimmed to the best possible advantage. Middle and latter part the same. Lat. by indifferent obs. 15° 55′ N. Long. " " 113° 24′ E.

Courses.	Winds.	
N. ¼ W. Distance by log, 225 miles.	S. S. W. breeze 8½ to 10 knots.	Aug. 6th. Begins with fresh breezes, and cloudy. All sail set. At 4, P. M., passed a barque standing eastward. Through the night strong breezes and squally, with rain and heavy sea. Latter part the same. Took in the royal studding sails. [The ship was now running into the path of the gale which had just passed.] At 11, A. M., [6th] heavy squalls, with rain in torrents. Took in all studding sails, royals, and top-gallant sails, and double reefed the topsails. No observation: sun obscured. Lat. by account 19° 54′ N. Long. " 113° 38′ W.
N. ½ W. N. N. ¼ W. N. N. by E. to N. W. and to N. E.	S. to S. S. E. S. by W. to S. E.	August 7th. From noon to 8, P. M., strong breezes and squally. Shook out reefs and set all light sails. Middle part, fine breezes and pleasant weather. At daylight made the Ass's Ears, bearing E. by N., distant 5 miles. At 7, passed the Great Ladrone. After part, wind S. E., and pleasant.

Chart showing the course of the wind in Raleigh's typhoon, on the 5th of Aug., civil time.



1. Levant on the 4th, S. W., fine breezes. 3. Canton, N. and N. W. all day.
2. Levant on the 5th, S. S. W., fresh breezes. 4. Raleigh, E. S. E. all day. violent typhoon.
Strong black line, supposed direction in which centre of storm moved towards W. N. W.

The above chart exhibits the course of the wind on the 5th The reader will perceive that the arrows, if prolonged, will meet in a central space of no great magnitude, where the storms must have been at that time, if it travelled regularly from the time of passing the Raleigh, at 3, A. M., of the 5th, till it passed Macao, a little after midnight, on the morning of the 6th, and at the moment when the barometer stood lowest at Macao, the wind was north at Canton, and S. with the Levant, both blowing exactly towards Macao, the point where the barometer stood lowest.

Again, it is worthy of remark, that the wind had been N. for several days at Canton, and immediately on the setting in of the typhoon, the wind became occasionally N. W., whereas, on the whirlwind theory, it ought to have turned more N. E. The same may be said of the wind with the Levant; on the passage of the typhoon, the wind changed round to S. E. as the storm passed away to the N. W. When the storm passed Canton, the wind changed round to the S. E., and continued blowing exactly towards the centre all the 6th, that is, on the supposition this storm moved in the same direction as the West India storms in this latitude, as it is known they curve rapidly, on reaching this latitude, towards the N. W. and N. As to the Lady Hayes, it is impossible to tell where she was, as her log leaves that undecided; but if she was near Macao at about 3, P. M., of the 5th, then from that to midnight, an arrow drawn in her locality would, for that time and for some time afterwards, point inwards towards the same space with the other arrows.

Mr. Redfield says, in the pamphlet before me, that "he considers the depression of the barometer in these tempests, as due to the rotative action, and the point of greatest depression, as indicating the true centre or axis of storm."

But this cannot be the case, for I have shown, in article 88, that it would require an outward motion of the air from the centre of two hundred and eighty feet per second to make the barometer fall an inch and a quarter, and of course a corresponding motion downwards in the centre of the storm. And Mr. Redfield says "he has but little objection to my formula on this point, subject to such corrections for countervailing tendencies as the case requires."[1] Now, as the wind tended inwards in this storm, the cause here alleged for the fall of the barometer is not the true one.

But Mr. Redfield has proposed a means of testing my theory in the following paragraph:

"*Test of Mr. Espy's Theory.* — The truth or error of Mr. Espy's theory may be ascertained by a very simple test. The hurricanes in the West Indies are known to move towards the W. N. W. nearly. Now, if this theory be true, at those islands which are in the centre of the storm's path, and where the gale is of the greatest duration, the wind will set in at about W. N. W., or exactly opposite to the course of the storm, and when its centre has passed over, will shift suddenly to E. S. E., and continue violent in this quarter till the storm is over. But if the gale be a whirlwind, as the facts seem to show, the wind at such places will set in at about N. N. E., and in the middle of the gale will shift nearly to S. S. W. — the wind varying from these points, and veering more gradually on either side, in proportion to the distance from the centre of the storm's track. That this corresponds, mainly, to the facts of the case, will hardly be doubted by those who institute the inquiry. The same test may also be applied to these storms, as they move in a N. E. direction along the shores of the United States; where, according to Mr. Espy's views, the gale, on the centre of its path, should blow, for the first part of its dura-

[1] See Journ. Frank. Inst. for Feb., 1837.

tion, from about N. E.; and in the second half, from nearly S. W. But all our inquiries serve to show that the gale is violent at N. E. only on the northern portion of the track of the tempest, and that the usual changes from this direction are not sudden, and to an opposite point of the compass; but instead thereof, we observe a gradual veering by the N. to the N. W."

I accept this test with the corrections which I am sure Mr. Redfield will allow, namely, on Mr. Redfield's theory if the wind sets in N. E., in storms on our coast, it never can change round to N. W., not even gradually, as he acknowledges it does. Second, this test can only apply to round storms, and if any shall be found with their N. E. and S. W. diameter much longer than their N. W. and S. E., then if such a storm moves towards the eastern quarter, the wind, on my theory, ought to set in from S. E., and change suddenly round to N. W., as a general rule.

It being always understood that allowance is to be made for oblique forces produced by various causes, but especially by an annulus or semi-annulus of increased barometric pressure to the N. or N. E. of the storm in its onward motion. Let us then put the theory to the torture.

Numerous examples were given in the storm of 1821, before investigated, all harmonizing with the test here proposed by Mr. Redfield, to which the reader is referred in articles 155, 156, and 157. Nor is the present storm of 1837 wanting in remarkable examples. The Ida changed round from N. E. to S. W. in twelve hours, having begun at N. N. E., and continued to blow, all day of the 18th, S. W., exactly towards the Rawlins and the Yolof, during which time the centre of the storm passed near both those ships. The Rawlins, also, which remained nearly stationary during the storm, as appears by her log, had the wind to set in N. E. by E., and changing round to N., after a calm of one hour, sprung up quick as thought from the *south west,* and it did not change again from that point. The Duke of Manchester also had the wind to change round from N. E. by E. through the E. to S. W., from which point it blew with violence till the afternoon of 19th.

The Yolof is a slight exception; but the phenomena with her will not agree so nearly with the centrifugal theory as it will with mine. The wind changed round with her from the E. N. E. to W. N. W.; how long it continued there is not mentioned. The direction of the wind is not mentioned from 8, P. M., of 13th, when it changed, till the 21st, when it was only a slight breeze from S. W. These are the only vessels having the centre of the storm passing near them. Let the candid reader judge how they satisfy the conditions required by the "test."

I will now give all the evidence on this point which I have at my command, of hurricanes, both in the West Indies and in the Bay of Bengal. It was mentioned before, that Edwards, in his History of Jamaica, vol. 3d, says that "all hurricanes begin from the N., veer back to the W. N. W., W., and S. S. W., and when got round to S. E., the foul weather breaks up." And he also says, in the same volume, "when the wind is S. and S. W. on the S. side of the island, it is often north easterly on the N. side, attended with heavy rains." As Mr. Edwards lived on the S. side of the island, it may well be asked if the winds on the N. side of the island, in time of hurricanes, do not change round from N. by E. with as much constancy as he says they do on his side round by W.? Also, Col. Capper, speaking of the great hurricane which occurred on the Coromandel coast, on the 29th October, 1768, page 60, says: "The wind began from the N. W., *as is usual at the commencement of these hurricanes.*" And Col. Reid says this same hurricane terminated S. E. (page 264.) And on next page he says, of another, quoting from Col. Capper, that it began in the N. W., and suddenly shifted to the eastward.

In the great Barbadoes hurricane, of 1831, August the 10th and 11th, as given by the author of the West Indian, the wind began N., varying from N. N. E. to N. N. W., during the first half of the storm, but strongest from the N. W. and N. N. W., and terminated from the S. E., though once it reached round, for a few minutes, near the end of the gale, to E., and soon got back to S. E., increasing to a hurricane, but unaccompanied with those fatal gusts which, from the western quarter, had effected so much destruction. The hurricane terminated two hours and a quarter after this, with strong breezes from E. S. E., and an hour after that, the dense body of cloud began to break up. (Page 38.)

Luke Howard, in his second volume, gives an account of a hurricane in St. Lucia on the 21st October, 1818. "The wind is stated to have set in N. W. at daybreak, and raged with tremendous violence, with occasional falls of rain, until 3, P. M.; when becoming southerly, it abated, but did not immediately cease."

It would appear, from the following account, that in latitudes as high as 25°, the storm sets in N. E. and terminates S. W. Mr. Howard, in his first volume, speaking of the Nassau hurricane of the 26th July, 1813, says: "At about half past 2, P. M., the hurricane attained its greatest height, and its acme continued, without interval, until 5, when *it suddenly ceased, and in the space of half an hour succeeded a calm*, so perfect that it can be compared only to that of death after the most dreadful convulsions. The inhabitants of the colony, well knowing the nature of hurricanes, took every precautionary measure within their reach, during the calm, or lull, to prepare for the second part, expected from the S. W., and which set in with great fury at about 6 o'clock, and continued until midnight, when it considerably abated, and soon after totally ceased. The first part of the storm from the N. E., raged without intermission, but the latter part appeared in heavy blasts of a few minutes' duration.

If the reader will refer back to the investigation of the great Barbadoes hurricane of 1780, he will find evidence of the most decisive character on this point. By examining all the accounts of the beginning of the storm at Barbadoes, he will discover, that though the wind began to blow from the N. E. with some violence, from the oblique force produced by the trade winds, which in this region are known to blow all the year, yet it backed round to N. W., and blew for many hours with its greatest violence, and then changed back again by the E. to the S. E., beyond which it did not go. Now, as the centre of the storm certainly passed within a few miles of the western side of this island, as shown before, for it passed between Barbadoes and the Albemarle, which left Barbadoes during the storm, the facts furnished here are even more conclusive than if it had been merely stated that the wind commenced N. W. and terminated S. E.

It is hardly necessary to remark, that as this storm, after passing Barbadoes, travelled nearly N. W., and not W. N. W., the conditions required by the "test" are fully answered.

In concluding the examination of this storm, I earnestly recommend to gentlemen who embrace the whirlwind theory of storms, to abstain from laying down rules to the practical navigator, founded on this doctrine, until it is better established than it is at present. And especially I recommend this course to Mr. Redfield, lest the practical evils arising from unfounded rules may diminish the lustre which his great discovery of the *translation of storms in space, and their continuity in time*, is beginning to shed round his name.

Storm of 18*th August*, 1830.

162. Col. Reid has copied into his work the documents furnished by Mr. Redfield concerning the storm of August,

1830. This storm, if indeed it was one, and not many, was upwards of 1000 miles long from N. N. E. to S. S. W., and at least five times as long as it was broad on the 17th. This fact, though it seems to have escaped the notice both of Mr. Redfield and Col. Reid, is abundantly proved by the following documents. For it will be seen that the brig Mary had a gale in lat. 27° 55′, lon. 76° 50′, which lasted till the 17th, and that, on the same day, the storm was felt at several points N. N. E. of the brig Mary, as far as Long Island Sound. And on the 18th, its length appears to be still greater, for it seems to have reached from lat. 28°, lon. 66°, where the wreck of the Julia was seen on that day, to lat. 41° 20′, long. 66° 25′, where the hurricane was tremendous on the 18th from N. N. E.

Whether this storm travelled side foremost exactly or not, cannot be ascertained by the documents collected. It certainly moved towards the eastward.

It is even doubtful whether it was one continuous storm, or composed of several. Yet it will be seen that it commenced at Wilmington, N. C., four hours sooner than at Charleston, S. C., and at Charleston one hour earlier than at Savannah, Ga.

But this does not prove positively that the storm was not the same at all three places, or that it moved backwards towards the S. W. For a storm of such great length moving side foremost, might have some portions of it advanced before the others, for aught that is known in the present state of the science. It is possible, however, that the Wilmington date is incorrect by twenty-four hours; and if so, the anomaly here spoken of would disappear. It is hoped that this matter will be settled hereafter. However it may be, the shape of the storm utterly precludes the idea of the whirlwind character, even if the direction of the wind had not been given in the several localities. But when the reader comes to the data below, imperfect as they are, he will discover this remarkable fact; that on the 17th, the wind in the Atlantic, some distance from the coast was blowing from the S. E. all the way from Georgia to Maryland, and at the same time on shore for that whole distance it was blowing from the N. W.; and that N. E. of Maryland, as far as Long Island Sound, the wind was N. E., and that the only record we have of a ship on the S. W. of this area, the Blanche, shows the wind on the 17th all day from the S. W., with fresh breezes at the end of a violent storm.

There are some deviations it is true, but not so great as to prevent the above statement being, in the general, true. I shall now give all the documents as copied by Col. Reid from Mr. Redfield, together with some additional ones which I have found in the newspapers of that time, and leave the reader, without a wood cut of this storm, to examine the documents for himself. In doing so, I would recommend him to have a map of the coast of the United States open before him.

Hurricane of 1830.

" This storm, or hurricane, was severe at the Island of St. Thomas, on the night between the 12th and 13th of August, 1830.

"On the afternoon of August 14, and the succeeding night, it continued its course along the Bahama Islands, the wind veering almost round the compass, during the existence of the storm.

"On the 15th of August, the storm prevailed in the Florida channel, and was very disastrous in its effects.

"In lat. 26° 51′, lon. 79° 40′, in the Florida stream, the gale was severe on the 15th, from N. N. E. to S. W.

" Late on the 15th, off St. Augustine, Florida, in lat. 29° 58′, lon. 80° 20′, the gale was very severe.

" At St. Andrews, twenty miles N. of St. Mary's, Georgia, from eight o'clock, P. M. on the 15th, to two A. M. on the

16th, the storm was from an eastern quarter, then changed to S. W., and blew till eight, A. M.

"Off Tybee, and at Savannah, Georgia, on the night of the 15th, changed to N. W. at nine, A. M. on the 16th, and blew till twelve, M.

"At Charleston, S. C. on the 16th, the gale was from the S. E. and E. till four, P. M., then N. E., and round to N. W.

"At Wilmington, N. C., the wind was from the E., and veered subsequently to the W.

In the interior of North Carolina, the storm was felt at Fayetteville.

"In the vicinity of Cape Hatteras, at sea, the storm was very heavy from the S. E. and shifted to N. W.

"A vessel bound from New York to Hayti, in the middle or outer part of the Gulf stream, about lat. 33°, lon. 72°, experienced the gale moderately from the S. W. and S. S. W., but with a heavy sea from a very westerly direction, and is supposed to have been on the outer margin of the storm.

"Another vessel, at about the same distance from the coast, experienced similar effects.

"Early on the morning of the 17th, the gale was felt severely at Norfolk, and also in Chesapeake Bay from the N. E.

"Off the Capes of Virginia, on the 17th, in lat. 36° 20′, lon. 74° 2′, 'a perfect hurricane,' from S. to S. S. E., from 5, A. M., to 2, P. M., then shifted to N. W.

"On the 19th, (17th?) in lat. 37° 30′, lon. 74° 30′, near the coast of Virginia, the gale was severe at E. N. E., and changed to W. N. W.

"Off Chincoteague, Md., precise distance from the coast unknown, the gale was severe between S. S. E. and N. N. E.

"Off the coast of Delaware, in lat. 38°, lon. 72°, 'tremendous gale,' commencing at S. E., at 1, P. M., on the 17th, and blowing six hours, then changed to N. W.

"At Cape May, N. J., the gale was N. E. Off Cape May, in lat. 39°, lon. 74° 15′, heavy gale from E. N. E. on the afternoon of the 17th of August.

"Near Egg Harbor, coast of New Jersey, the gale was heavy at N. E. on the same afternoon.

"Off the same coast, in lat. 39°, lon. 73°, the gale at E. N. E.

"In the same lat., lon. 70° 30′, 'tremendous gale,' commencing at S. S. E. and veering to N.

"At New York, and on Long Island Sound, the gale was at N. N. E. and N. E. on the afternoon and evening of the 17th.

"Off Nantucket Shoals, at 8, P. M., the gale commenced severe at N. E. by E.

In the Gulf Stream, off Nantucket, in lat. 38° 15′, lon. 67° 30′, on the night of the 17th, 'tremendous hurricane,' commencing at S., and veering with increasing severity to S. W., W., and N. W.

"At Elizabeth Island, Chatham, and Cape Cod, Mass., the gale was severe at N. E. on the night between the 17th and 18th of August.

"On the 18th, heavy gale from N. E. at Salem and Newburyport, Mass.

"Early on the 18th, in lat. 39° 51′, lon. 69°, severe gale from S. E., suddenly shifting to N.

"In lat. 41° 20′, lon. 66° 25′, 'tremendous hurricane' from N. N. E. on the 18th of August.

"On the night of the 18th, off Sable Island, and near Porpoise Bank, in lat. 43°, lon. 59° 30′, 'tremendous gale' from S. and S. W. to W. and N. W.

"In lat 43°, lon. 58°, severe gale from the S., the manner of change not reported. This remarkable storm seems to have passed over the whole route comprised in the foregoing sketch in about six days, or at an average rate of about 17 geographical miles per hour.

"The duration of the most violent portion of the storm, at the several points over which it passed, may be stated at from seven to twelve hours.

"The general width of the tract, influenced, in a greater or less degree, by the gale on the American coast, is estimated to have been from five to six hundred miles.

"Width of the hurricane portion of the tract, or severe part of the gale, 150 to 250 miles.

"Semi-diameter of the hurricane portion of the storm, 75 to 125 miles.

"Rate of the storm's progress from the Island of St. Thomas to Providence Island, Bahamas, 15 nautical miles per hour.

"Rate of progress from Providence to St. John's, Florida, 16 miles per hour.

"From St. John's to Cape Hatteras, N. C., 16½ miles per hour.

"From Cape Hatteras to Nantucket, on the south eastern coast of Massachusetts, 18 miles per hour.

"From Nantucket to Sable Island, off the south eastern coast of Nova Scotia, 20 miles per hour."

Extract of a letter from the Master of the Ship Illinois. — I sailed from New Orleans on the 3d of August, bound to Liverpool. Nothing worth notice occurred until the 15th of August, in lat 33° N., lon. 77° 10′, when there was a very heavy swell from the S., more than ever I had experienced before in this part, unless preceded by heavy gales. We had no indication of wind at this time, but there was a dull and heavy appearance in the S. During the day, the wind was light and at the S. E.; at night, it shifted to S. S. W. On the 16th, it was a fresh and wholesome breeze; so that with the help of the Gulf stream we ran at a great rate, steering N. E., and at noon we were in lat. 36°, lon. 73°. On the 17th, the wind continued steady at S. S. W., blowing a strong and wholesome breeze, but the appearance to the S. continued dull and heavy; the sea was smooth again, and we seemed to have outrun the southerly swell. At noon, lat. 37° 58′, lon. 69° 23′, we were still continuing to run about the course of the Gulf stream; the temperature of the water was 86° on the first of the 18th, (afternoon of the 17th, current time,) the wind backed to the S., and began to freshen in very fast; some heavy clouds arising in the S. W., with flashes of lightning in that quarter. At 8, P. M., the wind had increased to a strong gale; the weather at this time had an unusual appearance, but still it did not look bad. At 10, the wind had increased and we took in our sails and prepared for the worst. At 11 o'clock, the sea ran high and cross, which induced me to heave the ship to under a close reefed topsail. At half past 12, midnight, all was darkness; the heavy clouds which had been rising in the S. W. had overtaken us; the rain fell in torrents, and the lightning was uncommonly vivid; the wind had increased in the space of an hour from a moderate gale to a perfect hurricane. At half past 1, A. M., it began to veer to the westward. At 3, A. M., it was west, and rather increased in violence as it shifted. At daylight, the sky was clear, but the gale, if anything, rather increased in its fury; the sea was tremendous, and ran in every direction. At 7, the wind had got to the N. W., and at 9, it began to abate a little.

Extract from the Log of the Blanche. — At 1, A. M., of the 15th, wind north easterly, fresh breezes and squally. At 6, wind northerly, strong gales, with violent squalls; at 9, a hurricane; at 11 h. 30 m., wind changed to N. W. and blew more violently.

At 1, P. M., south westerly; at 2, more moderate; at 4, ditto weather; at 7, wind W. by N.; from 8 till midnight, strong gales and squally.

At 1, A. M., of 16th, wind S. by E., strong gales and squally; at 8, ditto weather; at noon, fresh gales and squally; at 1, P. M., wind S. W., fresh breezes and squally; at 6 and 8, strong gales.

At 1, A. M., of 17th, wind S. by W., fresh breezes and squally, with rain ; at 10, fresh breezes with a heavy swell ; at noon, fresh breezes and cloudy weather; at 1, P. M., wind S. W., fresh breezes and cloudy weather, and so till midnight. On the 15th, at noon, lat. 27° 15′, lon. 79° 35′. On 16th, lat. 30° 12′, lon. 79° 22′. On 17th, lat. 31° 42′, lon. 76° 59′.

Documents of this Storm, collected by J. P. Espy.

National Gazette, of 28th. — A Norfolk paper of Thursday, 19th. The canopy has been overcast for two days with clouds, indicating a storm. The wind blew very heavy on Tuesday night, 17th, from N. E.; shifted yesterday morning to N., and is still blowing a gale, with every appearance of something more severe in reserve. The tide was much higher yesterday in our harbor than on any day this season, overflowing most of the wharves.

Same paper of 26th. Crow Island, (North Santee) August 17. On Monday, the 16th, about an hour before day, we had a fall of rain, the wind at S. E. The rain fell in showers throughout the day, and the wind increased rapidly till 12, when it blew a hurricane. The wind continued from the same quarter, and increased till some time in the night. The tide rose higher than I ever saw it. Mr. Pinckney's vessel is on my island, near my barn.

Same paper of 31st. Ship Brilliant, on the 18th, lat. 40°, long. 71°, experienced a heavy gale of wind; had all the sails torn to tatters.

National Gazette of Sept. 7th. Schooner Neuse was wrecked on the S. side of Abaco, on the 15th.

Same paper of 8th Sept. The captain of the Neuse, says that the hurricane commenced on the afternoon of the 14th, and lasted 18 hours — the gale was not felt at Nassau, only 60 miles distant. The brig Native was wrecked on the 15th, on the S. W. part of Heneagus.

Same paper of 28th Sept. At New Orleans, it blew a gale between the 15th and 20th. The Mary Jane was driven on shore on the S. W. side of Abaco. Same paper of 30th. The Ceres fell in with the wreck of the Julia, in lat. 28°, long. 66°, on the 18th Sept.

Same paper of Aug. 31st. Sloop Excel was driven on shore on Wednesday, 18th, a little to the westward of Lynnhaven Inlet, during a severe blow from N. N. E.

Same paper of 30th Aug. At Wilmington, N. C., the New Hanover rode out the gale and went to sea on the 17th, the wind having subsided.

At Elizabeth City, N. C., the storm was terribly severe, with torrents of rain on Tuesday, the 17th. At Wilmington, N. C., it was on the night of the 15th, unless there is some mistake in the date — also very violent. In lat. 29° 58′, long. 80° 50′, the barque New Prospect, experienced a severe gale on the 15th and 16th, and was abandoned.

Same paper of 24th. At Charleston, S. C., the wind began to blow about midnight of 15th, from S. E. and E. S. E., and continued with increasing force, doing much mischief, till about 4, P. M., when it changed to N. W.

Same paper of 22d. Near Norfolk, Virginia, the corn on either side of the road was completely prostrate, and large trees were torn up by the roots, by the violence of the gale.

Same paper of 21st. There was a heavy blow from the N. E., on the 17th, off Great Egg Harbor.

American Sentinel, Aug. 25th. The Damon, on the 17th, off Chincoteague, experienced a severe gale from S. E. to N. N. E., and the T. Sophia, in lat. 37° 30′, long. 74° 30, had a gale from N. N. W.

Aug. 26th. At Savannah, on Sunday night, 15th, from 1 till 9 o'clock of Monday, the 16th, severe gales and heavy rains at intervals from N. E. Between 9 and 10, wind changed to N. W, whence it continued without abatement till 12, when it moderated and blew from the westward during P. M.

Barque H. Astor was, on the 19th, in lat. 30°, long. 68° 24′; had experienced, the day before, a tremendous hurricane from the N. N. E., — from New Orleans to New York.

Same paper of 27th. Brig Mary experienced a tremendous gale of wind on the 14th, in lat. 27° 59′, long. 76° 50′, from the E. N. E., which shifted to E. S. E., and it lasted three days. The John Shand was abandoned, having taken the gale on the 15th, in lat. 31°, long. 77° 20′.

Same paper of 28th. At Washington, N. C., a violent gale of wind from S. S. E., and rain on Monday night, 16th.

Same paper of Aug. 31st. Schooner Mary Ann, on 17th, lat. 38° 48′; severe gale from S. E. to S. S. E.

On 18th, in lat. 43°, long. 58°, heavy gale from the southward. Off the Highlands, blowing very heavy from the northward.

National Intelligencer, Aug. 26th. At Wilmington, N. C., about 8, P. M., of 15th, the storm set in with hard blowing from the E., and increased gradually till 9, when the wind began to rage with as much fury as we can remember in any former storm, and continued so for hours, changing to the W., between 11 and 12. On the same night, the wind at Charleston, began to blow freshly from the S. E., and E. S. E., about 12, continuing with rapidly increasing violence the succeeding day, and still blowing with diminished violence on the 17th.

American Sentinel of Aug. 24th. Aug. 18, lat. 37′ 20°, long. 75°, at 10, A. M., hove to in a heavy gale, S. E., At half past 12, wind hauled suddenly in to the N. and N. W., and blew a hurricane.

Same paper, Aug. 25th. Long. 72° 42′, lat. from 38′ 21° to 40° 30′, at noon, appearance of a storm; at 3 to 4, violent hurricane; in P. M., changed suddenly to N., increasing to a tornado. Same paper says the wind changed round by N. E., suddenly about 4, P. M., of the 16th, at Charleston, and S. to N. W.

Same paper, *Aug.* 28*th*. Schooner Packet, 30 miles S. E. of Tybee light, experienced the gale on the 16th, from S. S. E., shifting to W. S. W. Aug. 30. Capt. Hipkins experienced the gale on the 18th, in lat. 34° 45′, long. 73°, but sustained no injury.

Same paper of Aug. 31*st*. Ship Hellespont, off Sable Island, experienced a severe gale from S. W. to N. N. W., which lasted eleven hours. Sept. 1. A tremendous hurricane from N. N. W., on 17th, in lat. 40° 14′, long. 70°. Also ship Brilliant, lat. 40°, long. 71°, experienced a heavy gale from the N., for 4 hours, on the 18th.

Hospital, *Philadelphia*, *August*, 1830.

Day.	Thermometer and Wind.			Atmosphere.		
	7h.	12h.	3h.	7h.	12h.	3h.
14	68 E.	83 S. W.	85 S. W.	Fog.	Clear.	Clear.
15	74 S. W.	83 S.		Cloudy.	Cloudy.	Clear.
16	79 S. W.	91 S. W.	76 S. W.			
17	71 N. E.	71½ N. E.	69 N. E.	Rain.	Rain.	Rain.
18	61 N. W.	72 N. W.	74 N. W.	Clear.	Clear.	Clear.
19	64 N. W.	75 N. E.	79 N. E.	"	"	"

Rain on 15th, ...	0.16 inch.
16th, ...	1.10 "
17th, ...	61 "

These are all the documents which we have of this storm. They are very imperfect; yet they furnish proof of these three things: —

1st. The storm was several hundred miles longer from N. N. E. to S. S. W., than it was from W. N. W. to E. S. E.

2d. It moved eastwardly with a velocity not exactly ascertained; much less, however, than if its velocity should be estimated from its appearance along the coast of the United States.

3d. The wind set in generally out at sea from the S. E., and changed round to N. W.

163. From the following quotation, it would appear that a storm similar to this in shape had its longest diameter from E. to W., and travelled from N. to S. More information as to the shape of storms, and the direction in which they move, is much wanted.

"After a few days pretty fresh breezes from the S., clouds suddenly appeared in the N., and, by the motion of the water, we perceived that an equally strong wind was rising in that direction. The waves from the opposite regions foamed and raged against each other like hostile forces; but between them lay a path some fathoms broad, and stretching from E. to W. to an immeasurable length, which appeared perfectly neutral ground, and enjoyed all the repose of the most profound peace, not a single breath troubling the glassy smoothness of its surface. After a time, victory declared for Boreas, and he drove the smooth strip towards our vessel, which had hitherto been sailing in the territory of the S. wind.

"We presently entered the calm region; and while we had not a puff to swell our sails, the wind raged with undiminished fury on both sides. This strange spectacle lasted for about a quarter of an hour, when the N. wind, which had been continually advancing, reached us, and carried us quickly forward towards the place of our destination." — See *Kotzebue's New Voyage Round the World*, vol. 2, page 72. Off California.

An Account of the Fatal Hurricane by which Barbadoes suffered in August, 1831, *by the Editor of the West Indian.*

164. Page 33. — "On the 10th morning of the month, the sun arose without a cloud, and shone resplendently through

an atmosphere of the most translucent brightness. At 6, A. M., the thermometer stood as high as 83, which indicated the heat to be one degree greater than at sunset the preceding evening. At 8 it rose to 85, and at 10 to 86, at which hour the gentle breeze which had fanned the country died away. After a temporary calm, high winds sprang up from the E. N. E., which in their turn subsided; calms for the most part then prevailed, interrupted by occasional sudden puffs, from between the N. and N. E. At noon the heat increased to 87, and at 2, P. M. to 88, at which time the weather was uncommonly sultry and oppressive. At 4 the mercury sank to 86. Until that hour the observations on the weather, as here detailed, were made in Bridgetown. At 5, P. M. the writer, being about a mile and a half to the northward of the town, remarked the clouds gathering very densely from the N.; the wind commenced to blow very freshly from the same point.

"A shower of rain presently fell, and was succeeded by a sudden stillness, to which a solemnity was added by the dismal blackness of the horizon all around. The impenetrable body of cloud extended upwards towards the zenith, leaving there an obscure circle of imperfect light, the diameter of which appeared to be about 35 or 40 degrees of the celestial concave. This dismal circle remained at rest for a very few moments; when the scud of it was seen to be in a state of ebullition; the dense mass of clouds all around was agitated, and separating bodies of it were quickly dispersed to all points of the compass. From 6 to 7 the weather was fair and the wind moderate, with occasional slight puffs from the N.; the lower and principal stratum of clouds passing fleetly towards the S., the higher strata and scud rapidly flying to various points; after 7, the sky was clear and the air calm; tranquillity reigned till a little after 9, when the wind again blew from the N. At half past 9 it freshened, and moderate showers of rain fell at intervals for the next hour. Distant lightning was observed at half past 10, in the N. N. E. and N. W. Squalls of wind and rain from the N. N. E., with intermediate calms, succeeded each other until midnight, the thermometer in the meantime varied with remarkable activity; during the calms it rose as high as 86, at other moments fluctuated from 83 to 85.

"After midnight, the continual flashing of lightning was awfully grand, and a gale blew fiercely from between the N. and N. E. At 1, A. M. of the 11th the tempestuous rage of the wind increased; the storm, which at one moment blew from the N. E., suddenly shifted from that quarter, and burst from the N. W. and intermediate points. The upper regions were, from this, illuminated by incessant lightning, but the quivering sheet of blaze was surpassed in brilliancy by the darts of electric fire which were explored in every direction. At a little after 2, the astounding roar of the hurricane, which rushed from the N. N. W. and N. W., cannot by language be described. About 3, the wind occasionally abated, but intervening gusts proceeded from the S. W., the W., and W. N. W., with accumulated fury. The lightning also having ceased for a few moments only at a time, the blackness in which the town was enveloped was inexpressibly awful. Fiery meteors were presently seen falling from the heavens; one in particular, of a globular form, and a deep red hue, was observed by the writer to descend perpendicularly from a vast height. It evidently fell by its specific gravity, and was not shot or propelled by any extraneous force. On approaching the earth, with accelerated force, it assumed a dazzling whiteness and an elongated form, and dashing to the ground in Beckwith Square, opposite the stores of Messrs. H. D. Grierson and Co., it splashed round in the same manner as melted metal would have done, and was instantly extinct. In shape and size, it appeared much like a common barrel shade. Its brilliancy, and the sparkling of its particles on meeting the earth, gave it the resemblance of a body of quicksilver of equal bulk. A few minutes after the appearance of this phenomenon, the deafening noise of the wind sank to a solemn murmur, or, more correctly expressed, a distant roar, and the lightning, which, from midnight, had flashed and darted forkedly, with few and but momentary intermissions, now, for the space of nearly half a minute, played frightfully between the clouds and the earth, with novel and surprising action; the vast body of vapor appeared to touch the houses, and issued downward flaming blazes, which were nimbly returned from the earth upward. The corruscations, for the short space of time they continued, instantly succeeding each other. This strange quivering, or darting, of flashes down and up, may be compared to the miniature blazing produced by the rapid and irregular discharge of opposing artillery closely engaged. Whilst this remarkable phenomenon proceeded, the earth vibrated in a manner, and in time, answering with the action of the lightning. Twice, or more, when the corruscations were more brilliant and severe, but less rapid in succession, the earth received corresponding shocks. The moment after these singular alternations of lightning, the hurricane again burst from the western points with violence prodigious beyond conception, hurling before it thousands of missiles, the fragments of every unsheltered structure of human art. The strongest houses were caused to vibrate to their foundations, and the surface of the very earth trembled as the destroyer raged over it. No thunder was at any time distinctly heard; had the cannon of a hundred contending armies been discharged, or the fulmination of the most tremendous thunderclaps rattled through the air, the sounds could not have been distinguished. The horrible roar and yelling of the wind, the noise of the tumultuous ocean, whose frightful waves threatened the town with the destruction of all that the other elements might spare, the clattering of tiles, the falling of roofs and walls, and the combination of a thousand other sounds, formed a hideous din, which appalled the heart, and bewildered, if not alienated the mind. No adequate idea of the sensations which then distracted and confounded the faculties, can possibly be conveyed to those who were distant from the scene of terror. The sheltered observer of the storm, amazed and in a state of stupor, was fixed to the spot where he stood; the sight and the hearing were overpowered, and the excess of astonishment refused admission to fear. What must have been the mental agonies of those wretched fugitives, who, destitute of a place of refuge, were the sport of the dreadful tempest, and alive to all its horrors! This unparalleled uproar continued, without intermission, till half past 4, the raging blast coming from the W., and other points to the southward of it, attended with frequent dashing and pelting rain. After 5 o'clock, the storm now and then for a few moments abated, at which time the dreadful roar of the elements having partially subsided, the falling of tiles and building materials, which, by the last gust, had probably been carried to a lofty height; the shrieks of the suffering victims; the cries of the terrified inhabitants, and the howlings of dogs, were clearly audible, and awakened the mind to an apprehension of the havoc and carnage which had been, and still were, desolating the colony.

"At half past 5, after a dreadful gust from the W. S. W., the wind suddenly chopped round to the E., from whence it blew a moderate gale, which in a minute increased, and changing to the S. E., a hurricane again raged, but unaccompanied by those fatal gusts, which, from the western quarter, had effected so much destruction. Torrents of rain at this time fell. At 6, the hurricane blew suddenly and tremendously from the S., driving the sheets of rain horizontally before it. This continued till 7, when the wind, then from the S. E., was more moderate; but floods of rain still deluged the ruins of the town, and the population, who were now destitute of any shelter. At 8, A. M., strong breezes blew from the E. S. E.; after that hour the dense cloud began to break up, and at 10, the sun for a few moments darted its rays over a prospect of wretchedness more replete with real misery and sickening to the heart, than the field of battle after a sanguinary contest."

The centre of this storm appears to have passed a little to the N. of Barbadoes, and over the southern extremity of St. Lucia.

On the evening of the 10th, no unusual appearance had been observed at St. Lucia; but as early as 4 or 5 o'clock next morning, the garrison, stationed near the northern extremity of the island, began to be alarmed; some hut barracks blew down, and the wind was then nearly N.

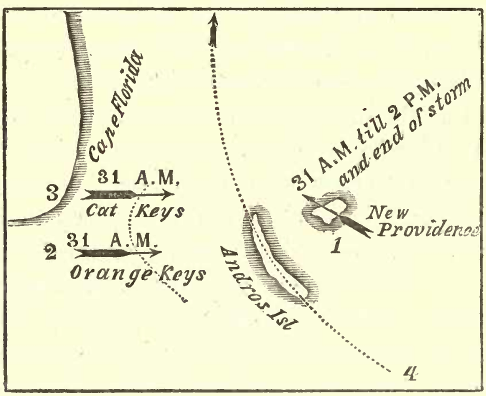
The storm was at its greatest height between 8 and 10 o'clock in the morning; but from that time the wind gradually veered round to the E., diminishing in force and dwindling, as it were, to nothing in the S. E., and it was succeeded by a beautiful evening, with scarcely a breath of wind.

At the southern extremity of the island, the most violent part of the storm is reported to have been from the S. W. At St. Vincent, the garrison was at Fort Charlotte, near the S. W. point of the island; and there the wind first set in from N. W., veering to W. and to S. W., raising the water in Kingston Bay so as to flood the streets; and it unroofed several of the buildings in the fort, and blew down others; but at Martinique, (as will be seen from the following report printed in the "*London Shipping List*," for 1831,) the wind was easterly during the gale.

"Paris, September 15, 1831.—The Martial arrived at Havre from Martinique; sailed on the 15th of August. On the 11th of August, a gale at E. was experienced there which lasted six hours. The plantations suffered severely. Two vessels belonging to Bordeaux, and all the Americans at anchor in the road of St. Pierre, were driven out to sea. The army schooner, the duke of York, on her return from Trinidad to Barbadoes, during this hurricane, was in sight of Granada in the evening, and to the eastward of that island. About midnight she first began to experience hard squalls from the N. W., which caused the master to take in sail. The squalls increased until the vessel could carry no sail at all, and she was expected every moment to founder. Happily, at day light, those on board of her unexpectedly found themselves drifted close to the island of Barbadoes.

These are all the accounts we have of this hurricane, yet, meagre as they are, the reader will perceive that during the last two hours of the hurricane at Barbadoes, after the wind changed round there S. E., it was N. at St. Lucia, and certainly between N. W. and S. W. at St. Vincent, and therefore at this time it was blowing inwards towards a central space, not far, undoubtedly, from where the middle of the storm then was.

165. From Reid's Law of Storms, page 51, is extracted the following account, which I have accompanied with a chart.



1. There was a violent gale at Nassau, New Providence

from the east and south east, on the 29th July, which continued until two P. M. of the 31st.

2. The packet Sea Gull, on the night of the 30th July, in coming through the narrow part of the Florida channel, experienced a very heavy gale from the north west, which increased on the morning of the 31st, with torrents of rain. About ten, A. M. the wind was west, and the vessel was anchored, lat. 24° 40′, long. 79° west, twelve miles south of Orange Keys. On the morning of August 1, the wind increased and blew a perfect hurricane for about four hours, when it moderated a little, and veered to the south west, and at three, P. M., she made sail off the reef.

3. Barque Baltimore, from Havana, experienced heavy gales from the westward, on the 31st July, which continued till the first of August. She was over the reef, on the Bahama banks, by the Cat Keys, and compelled to anchor, and ride out the gale. When the weather cleared, on the second, she saw three vessels on the reef, wrecked; but she was unable to lend assistance.

4. Probable direction in which the centre moved.

I now take leave of Col. Reid for the present, thanking him most sincerely for the many interesting facts with which he has enriched the science of meteorology.

As to his water spouts—I hope I shall be able to prove, in Sec. VII., by numerous facts, that the wind blows inwards, at the sides, upwards in the middle, and outwards above, in this meteor, as well as in the great storms above investigated.

Dr. Piddington's Storms.

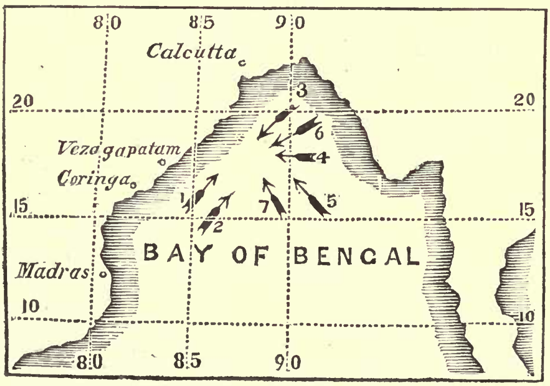
166. In the Journal of the Asiatic Society of Bengal, for 1840, p. 397, Dr. Henry Piddington gives an account of a great storm, which did much damage at *Coringa* and Vizagapatam, on the east coast of Hindoostan on the afternoon and night of November 16th, 1839.

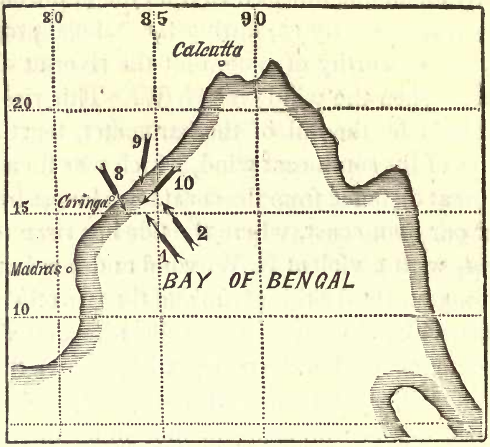
This storm seems to have commenced on the 14th, near the middle of the Bay of Bengal, and increased in violence until it reached the coast, moving towards the west, or west by north, with a velocity of about five and a half miles an hour. On reaching the coast, it seems to have broke up suddenly. I have copied, from Dr. Piddington's account, the following logs, and embodied the whole in two charts, by means of which the reader can see at a glance of the eye, how the wind blew on the evening of the 15th, and on the morning of the 16th, at which times the storm was fully formed and at its maximum violence. It is worthy of particular remark, that to the ships as far as 91° or 92° east longitude, the wind freshened up from the eastward, and continued in that quarter during the whole of the gale, while all the other ships, which had the violence of the gale to pass over them, had the gale *first* in some westerly direction, and *last* from some point easterly. From this circumstance alone, it follows (as the storm itself certainly moved towards the west) that the wind blew inwards towards the central parts of the storm.

Again, as Hope Island, near Coringa, was undoubtedly a little north of the central line along which the storm passed in its motion towards the west, and as the wind there, on the near approach of the centre of the storm, raged with great violence from the N. W., and changed round by the N. to N. E. and E., and next day to the S. E. This is another circumstance which proves that the motion of the wind was inwards. If this storm was a whirlwind, the wind at Hope Island, having once blown from N. W., must have veered round by west. As to the barometer, its fall seems to be confined to the limits of the storm, which was probably not more than two or three hundred miles in diameter. By examining the records, given by Dr. Piddington, I find that the barometer fell from midnight of the 16th, to midnight of the 17th, at Coringa, about an inch, whilst at Calcutta, perhaps only about 500 miles N. E. from there, the barometer was stationary, or nearly so, during the whole progress of the storm. It is worthy of note, that the river at Coringa, began to rise when the wind was N. W. This rise was no doubt produced by the fall of the barometer, together with the influence of the south east wind, which was then prevailing, at no great distance from the coast. Instances have been known, on our own coast, where the tide has risen to a very great height, with a violent N. W. wind and low barometer.

Dr. Piddington thinks this storm and the two others which follow, were whirlwinds, moving in the direction that Mr. Redfield contends for, but the reader will perceive that there was a decided inward motion, if not exactly to a central point, at least to a central space or line, in all these storms. It may be added that the irregularities which appear in these storms, may well depend on the wide extended rains which seem to have accompanied them all.

The first chart below exhibits the course of the wind on the night of the 15th, till about midnight; the second, the course of the wind, on the morning of the 16th.





EXPLANATION OF THE WOOD CUTS.

No.

1. Arethusa, at 2, P. M., of 15th, increased to a hurricane, W. N W., changed at 4, to W. S. W., and at 9, S. S. W.; at 11, moderating, at midnight, S. S. E., between 15 deg. and 16 deg. lat. and 86 deg. to 85 deg. long. Wind moderating at 4 A. M. of 16th, at 6, S. E., and so all day of 16th and 17th, much rain from the 12th till the 16th, with the wind N. E. till 3 or 4 A. M. of 15th, changing round to N. at 6 A. M., on 16th, lat. 15 deg. 30 min. long. 85 deg. 9 min.
2. Ripley (Brig) violent gale for 24 hours, wind N. N. W. and N. W. on 15th, changing at 4 P. M., W., and at 6 P. M., W. S. W., moderating a little; bar. all day from 29.30 to 29.40, midnight, S. W., next morning at 6, S. S. W., and at 9, S. by E., and at 10 P. M. it ceased raining, with strong breeze and fine clear weather; wind S. E., all 17th, on night of 15th, between lat. 14 and 15, and long. 86 deg. and 87 deg. Much rain from 13th till 10 P. M. of 16th. (? A. M.) on 16th, lat. 15 deg. 38 min. long. 86 deg. 57 min.
3. Le Balguerie, lat. in night of 15th, about 19 deg. N., long. about 88 deg. E. Much rain and squally P. M. North easterly. On 14th, and squally, N. E. and N. N. E. on night of 15th, moderating a little at midnight; at daylight E. N. E. and E., squally and rain.
4. Duke of Bedford, blowing hard E. from noon of 15th till noon of 16th, except a short lull of 20 minutes, at 11 P. M. of 15th. About lat. 18 deg. 25 min., long. 89 deg. 20 min., wind continued light, E. on the 17th, having cleared on night of 16th. Barometer on 14th and 15th, 29.80 minim., wind south easterly from the 12th, on which day the lat. was 11 deg. 41 min., long. 91 deg. 21 min., wind S. E., fine.
5. Ship Cashmere, Merchant, lat. 17 deg. 30 min., long. 92 deg. 25 min., gale increasing on 14th throughout, E. S. E., continuing on A. M. of 15th, with heavy squalls and rain, and so till midnight, S. E. On 16th, fresh breezes and clear, E. S. E., same on 17th. Strong easterly breeze from midnight of 12th, on which day the ship was in lat. 16 deg. 58 min. long. 92 deg. 25 min., increasing breeze from E. N. E.
6. Barque Sumatra, about lat. 18 deg. 50 min., long. 89 deg. 20 min. E. N. E. all day and night of 15th, heavy gales with constant rain all night and next morning till noon, and at sunset heavy squalls and rain at intervals. Wind E. S. E. to 8, P. M., then S. E. by E. till next day, weather moderating all day 17th. On 16th, lat. 18 deg. 40 min. long. 89 deg. 12 min.
7. Steamer Ganges, lat. about 17 deg., long 89 deg. 50 min. S. E., hard gales in morning of 15th, decreasing all day, and at midnight stiff breeze, S. E.; next morning and all day moderate, S. E. by E. and E. by S.
8. Hope Island, off Coringa, on 16th the wind commenced blowing from the north eastward with drizzling rain till 1, P. M., when it shifted to the N. N. W. and terminated in a gale. About 2, P. M. the wind shifted N. W. when the river commenced rising, and at 8 the island was under water. At 10,

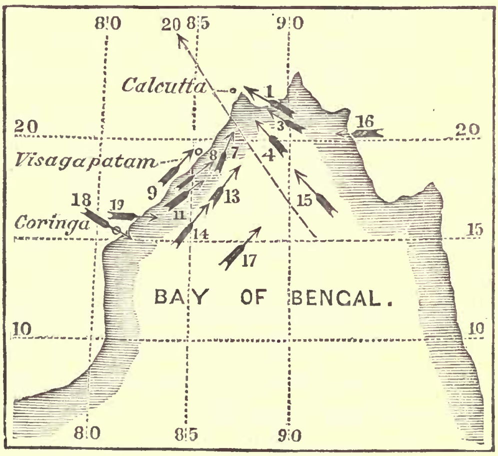
it shifted to N. E. and blew a dreadful hurricane, and at 12 it was eastward, and at 1, A. M., of 17th it was south eastward, tremendous strong; at day-break the weather cleared up. Barometer fell about one inch.

9. Vizagapatam. Wind increased from N. E. all night of 15th, to a decided gale, and on the morning of 16th, it veered to the northward, and blew hard the whole day from N. to N. E., mostly N. strongest about 10, A. M. In the evening, it got back to the eastward, and blew hard and steadily during the night east, north east to east, without much rain. In the morning it moderated and shifted to the S. E., and veering to the south, it became more moderate with showers of rain during the day, on the morning of 18th, the gale had subsided. Gale was not much felt thirty miles N. by E., nor forty miles west from this place.

10. Indian Queen stood out to sea from Visagapatam at 1 h. 30 m. A. M., of 16th, wind N. to N. N. E., very threatening at 9, A. M., N. E., strong gales increasing at noon; hove to under main trysail. At this time about seventy miles S. E. from Visagapatam; at 6, P. M., wind E. N. E. gale increasing; wind still veering to S. E. by midnight, still increasing, abating at 6, A. M., south, then off Juggernautporem, near Coringa.

June Storm.

168. I have also copied from Dr. Piddington an account of a great storm which occurred on the 5th of June, 1839, at the head of the Bay of Bengal. It is accompanied with a chart and arrows, showing the course of the wind on that day.



No.
1. Calcutta E. S. E. strong.
2. Diamond Harbor E. to S. S. E., strong with heavy rain. lat. 22 deg. 11 min., lon. 88 deg. 11 min.
3. Kedgree, same. lat. 21 deg. 52 min. lon. 87 deg. 59 min.
4. Hope, S. S. E. very hard all night of 4th and day of 5th, lat. 21 deg. 26 min. lon. 88 deg. 07 min.
5. Beacon, same as Diamond, lat. 21 deg. lon. 88 deg. 27 min., S. E. and S. S. E. blowing heavy; but more moderate than last night, [not marked for want of room.]
6. Jane, same.
7. Amherst, lat. 20 deg. 3 min. lon. 87 deg., perfect hurricane all night of 4th, till 2 A. M., S. to S. S. W., then began to

moderate all day of 5th, under foresail and close reefed maintopsail, with rain.
8. Krishna, lat. 19 deg. 40 min., lon. 86 deg. 27 min., dead calm at 1, P. M , and wind suddenly veered round from N. and N. W. to S. W., and blew a furious gale, moderating at 6, next morning.
9. Juggernaut Pagoda, lat. 19 deg. 48 min., lon. 85 deg. 48 min., gale N. on 4th, on 5th, S. W.
10. Mary Somerville, 18 miles S. W. half W. from above, strong gale S. W., increasing to a severe gale S., being then 15 miles S. of E. from above. On the 4th, fresh gales W., with heavy rain.
11. Justina, lat. 18 deg. 15 min., lon. 85 deg. 11 min., on the 5th, S. W., moderate; very severe on the 4th, P. M., S. W. by S.; on 4th, W. S. W., severe gale veering to S. W., P. M.
12. Ann Lockeby, same as Amherst all night of 4th and 5th, till 4, P. M., with heavy rain.
13. Eden, lat. 18 deg. 1 min., lon. 86 deg. 52 min. Hurricane W. S. W. all night of 4th and 5th till 4, P. M., with heavy rain.
14. Mobile, lat. 16 deg. 20 min., lon. 85 deg. 20 min., S. W. veering to S. S. W. more moderate rain in P. M.
15. J. W. Dare, lat. 18 deg. 44 min., lon. 93 deg. 50 min., S. E. on 5th, smart breezes on night of 2d and morning of 3d, heavy gale from S. S. E. The gale was then at its height, having begun about noon of 2d. It reached the Krishna at 1, P. M. of 5th, with its centre.
16. Akyab, lat. 20 deg. 5 min., lon. 92 deg. 50 min., E. gales, with rain for 24 hours.
17. Lady Macnaugten, lat. 14 deg. 51 min., lon. 88 deg. 16 min., on 4th and 5th, W. by S. to S. W. by S. very severe gale, moderating on 5th.
18. Masulipatam, W. N. W. blowing very fresh on 4th and 5th.
19. Laurel Amelia, lat. 17 deg. 22 min., lon. 83 deg. 44 min., on 5th, westward a hurricane. On 4th, west, hard gales. Lat. 16 deg. 56 min., lon. 82 deg. 58 min.
20. Direction of centre of the storm.

This storm was of great length from south east to north west, for its south east border had hardly left the J. W. Dare, on the morning of the 4th, when its north west border had reached Chuprath, lat. 25° 40′, long. 84° 40′. How great its diameter in the other direction is not known. But one thing is certain, that all the winds on the north east side were from eastward or south eastward; and all the winds on the south west side were from the south westward, as far as known, after the centre of the storm passed, with the exception of No. 18 and 19, at a great distance from the centre.

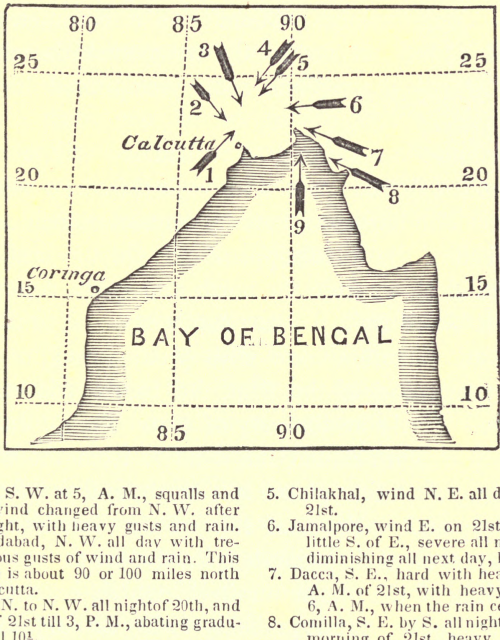
Dr. Piddington makes the centre of this storm, at noon of the 5th, lat. 19° 25′, long. 87° 1′. He seems to think that all these storms were round, as I suppose all must, who believe in the centrifugal doctrine.

September Storm.

169. Dr. Piddington has also given an account of a great storm, which occurred at the head of the Bay of Bengal, on the morning of the 21st September, 1839. It will be seen by the accompanying chart and extracts from the Doc-

tor's account, that the centripetal tendency of the wind in this storm was quite marked.

Chart, showing the course of the wind on the morning of the 21st Sept., 1839, in the storm at the head of the Bay of Bengal.



No.

1. Calcutta, S. W. at 5, A. M., squalls and rain, wind changed from N. W. after midnight, with heavy gusts and rain.
2. Moorshedabad, N. W. all day with tremendous gusts of wind and rain. This station is about 90 or 100 miles north of Calcutta.
3. Maldah, N. to N. W. all night of 20th, and day of 21st till 3, P. M., abating gradually till 10½.
4. Rungypore, at 10 o'clock 30 min., A. M., of 20th, a storm commenced N. E., and continued till 1, A. M. of 21st, but increased again, until from 8 to 10 A. M., it blew very hard between N. and N. E.
5. Chilakhal, wind N. E. all day 20th and 21st.
6. Jamalpore, wind E. on 21st, varying a little S. of E., severe all night of 20th, diminishing all next day, heavy rain.
7. Dacca, S. E., hard with heavy rain at 3, A. M. of 21st, with heavy squalls till 6, A. M., when the rain ceased.
8. Comilla, S. E. by S. all night of 20th, and morning of 21st, heavy showers of rain.
9. Burrisaul, very violent S. E. till after midnight of 20th, then settled S., changing to W. on morning of 21st.

Professor Loomis's Storm.

170. On the morning of the 18th December, 1836, says Professor Loomis,[1] the barometer was at an unusual height

[1] Trans. Am. Phil. Soc., vol. vii. p. 150, new series. (Prof. Elias Loomis, of Western Reserve College, Ohio.)

along the line of the Mississippi river, while in the eastern States it was quite low, but rapidly rising; and the wind east of Detroit was then very uniformly blowing from the west. In the valley of the Mississippi the barometer was at its maximum, and the winds consequently were light, and their directions various. There was a barometric minimum at this time not far to the west, towards which the whole [lower ?] atmosphere soon precipitated itself with great violence.

The barometric maximum travelled easterly, and on the morning of the 20th, it passed through the eastern extremity of Maine. The barometric minimum now coincides nearly with the bed of the Mississippi river. On the west of this line the wind blows from the north and north west; on the east side it blows from the east south east and south. The winds in this direction blow with great strength.

On the morning of the 21st, the barometric minimum had arrived nearly at the city of New York. In all the middle and western States, the wind is from the west and north west. At a few places it is north, and at a few others south west; and on the east side of the barometric minimum the prevalent direction is from the south east.

In the line of the minimum itself, which extended from Florida to Quebec [and probably twice as far] the mean direction of the wind, which was very strong, was about south 5° east. At a certain distance, however, from the line of minimum, the courses are very uniformly south east. In the afternoon of the 21st, the line of minimum had nearly reached Boston, and the north west wind had become the prevalent one throughout almost the entire United States. In the extreme west, the wind had begun to moderate its violence, and at Fort Jesup it was north east; at Fort Gibson, east, and at Jefferson Barracks, south east.

On the 22d, the north west wind was almost every where the prevalent one, particularly in the eastern States, where it blew invariably from some point between the north and south west. On the southern border it blew very uniformly from the north, and in the western States the winds were becoming light and irregular, veering round to the south and south east, as they had done three days before.

At the rate with which the storm moved across the western States, it would have travelled from the Rocky Mountains to Fort Levenworth in sixteen hours. And Professor Loomis says there can be no reason seen why the storm should not have extended to the Rocky Mountains. But he thinks it could not have come from beyond them; for even if a warm moist current should blow across those mountains, it would be a cold, dry air when it descended on the other side.

So far, then, as rain is concerned, the Rocky Mountains must be supposed the western boundary of the storm.

I am unable, says the Professor, even to conjecture the probable limit of the storm on the north. The oscillation of the barometer increased pretty uniformly from the most southern station [lat. 20°] to the most northern [Quebec]. Why should not the storm have extended as far to the north as it did to the south of this station? On this supposition the northern limit would be near the arctic circle. At a little distance from the line of barometric minimum, on the east, the wind was from the south east, while on the west, it blew from the north west. These were both violent winds, probably not less than forty miles an hour. But how is it possible for two winds not far separated from each other to blow violently towards each other for hours, and even days, in succession?

The Professor here endeavors, at some length, to prove that the south east wind ascended from the surface of the earth, while the north west wind flowed under it; and that the south east wind, on ascending, divided, part going to the south east and part to the north west. The cause of the commencement of the south east wind was the fact that the greatest depression of the barometer was at some point north of the United States. The chief cause of the depression of the barometer, he says, was this: "The south east wind, which accompanied the rain, moved with an accelerated velocity. The particles, therefore, of air at one extremity of the current must have left those of the other extremity at an increased distance. Hence a mechanical rarefaction, and of course diminished pressure, near the central line of greatest depression: part of the depression, he thinks, is due to the upward motion of the air." With great respect for the opinion of the author of this very able and most important paper, I dissent entirely from the views here expressed as to the causes of the barometric depression. There is but one cause of the *great* barometric fluctuations — the change of weight of the whole column of air from the surface of the earth to the surface of the atmosphere; and this weight can be affected to any considerable extent only by heat — sensibly, however, by moisture. The Professor thinks it cannot depend principally on heat, for the barometer sometimes falls as the temperature of the air diminishes. But if the doctrine every where taught in this book is correct, the upper regions of the air at this very time are in temperature greatly above the mean, containing the latent caloric of vapor recently condensed in a neighboring storm of rain or snow. An upmoving current of air is a *proof* that the barometer is depressed where it exists below what it is in the borders of the upmoving column; but it is not the *cause* of that depression. On the contrary, if the air were forced in on all sides by mechanical means, by impulsion and not by aspiration, towards a central space, it would *ascend* over that space, and at the same time the barometer would *rise;* and the laws of spouting fluids teach us that the rise of the barometer would be in proportion to the square of the velocity of the ascending air. Indeed, there is no conceivable way of preventing an accumulation of air over a space towards which the air below blows, and thus a rise of the barometer under the ascending column or current, but by supposing an outward motion of the air above; and this is true in all cases where the motion of the air is inwards below, even if there should be a gyration or whirlwind there. Now, as the barometer stands low in the middle of all storms, it follows that the air must run out above as fast as it runs in below; and if Professor Loomis will calculate the expansion of the air in the cloud, due to the evolution of the caloric of elasticity and caloric of fluidity, during the condensation of vapor which formed the cloud, he will find it adequate to produce the effect in question, without calling in the aid of any other causes. It is not the acceleration of the air below towards the centre of the storm which causes the barometer to stand low there; it is the out-spreading of the air above, which is the cause both of the fall of the barometer and of the inward motion of the air below. In the case of tornadoes, it has been supposed that the outward motion of the air above was produced by the centrifugal force of a mighty whirlwind in those lofty regions; and Mr. Osler, finding there was no whirl below, applied that conjecture to the great Liverpool storm of the 6th and 7th of January, 1839; but since that storm, as well as this, was of immense and unknown length from N. N. E. to S. S. W., this conjecture cannot be true; and therefore it seems probable, from this fact alone, that it is not true in case of tornadoes.

Besides, it is altogether unphilosophical to suppose a whirlwind above, without showing some possible way in which that whirlwind could be produced, which I think never can be done. Professor Loomis has not attempted to show that the cause which I assign for the fall of the barometer in storms, is inadequate to produce the effect; though he clearly shows that not one of the causes which others have assigned can account for the phenomenon.

If the cause, however, which he assigns, is the true one, it was unnecessary to mention mine, for the establishment of one is the refutation of the other.

But the professor also thinks that " part of the depression is due to the upward motion of the air."

To this proposition I cannot assent.

Let the reader imagine one barometer in the inside of a storm cloud near the top, ten miles from the surface of the earth, and another at the same elevation on the outside of the cloud. Now though there is a strong current of air rushing upwards, past the barometer in the cloud, yet that barometer will stand higher than the one on the outside which is in no such under current. (175.)

The reason it will stand higher is that there is more air over the one in the top of the cloud, than over the other on account of the expansion of the air in the cloud, and its swelling up to the very top of the atmosphere and rising higher there than in surrounding regions. Indeed the very fact, that the air spreads outwards on all sides in these high elevations from the centre of the storm, which professor Loomis admits, and indeed proves, is itself an absolute proof that the barometer stands higher at the place *from* which the air spreads out, than it does at the places *towards* which the air moves on the same horizontal level.

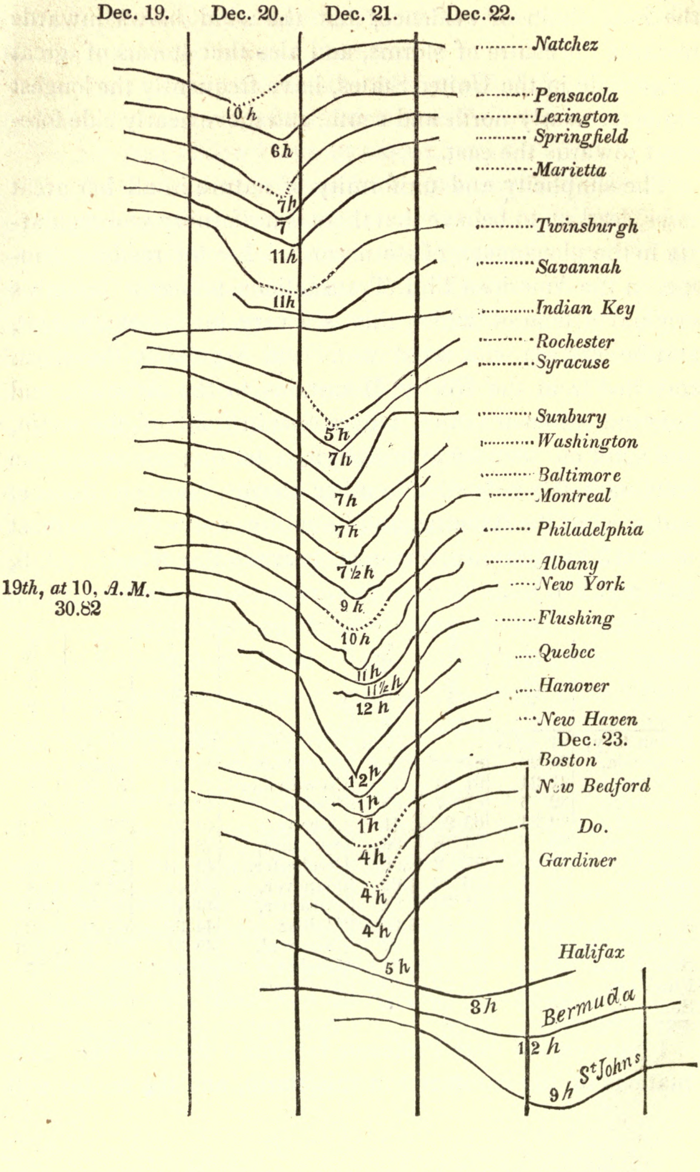
In the torrid zone at the surface of the earth, the barometer stands lower than it does at the arctic circle, yet no one who thinks will doubt that at ten or fifteen miles above the earth's surface, the barometer would stand higher in the warm latitude than in the cold, because it is farther to the top of the atmosphere where the air is more expanded by heat.

The following chart and table of barometric fluctuations, are so highly important, that I copy them entire, with the table of latitudes and longitudes, as a beautiful specimen of inductive philosophy. Professor Loomis, in the investigation of this magnificent storm, has added another link to the long chain of evidence, that the wind blows inwards towards the centre of storms, and also that storms of great magnitude in the United States, have frequently the longest diameter nearly north and south, and move nearly side foremost towards the east.

The simplicity and uniformity of nature in all her great laws, lead us to believe that there is uniformity and regularity in the phenomena of storms also. Let the reader examine, in the American Phil. Transactions, professor Loomis's original article of which this is a very imperfect abstract, and he will see with what wonderful regularity the storm travelled from the Rocky Mountains to the Atlantic, and how the barometer every where rose in front of the storm, and sunk on its near approach, and let him compare these facts with those detailed in other storms, both on the east and west of the Atlantic, and he will perceive that a most wonderful uniformity seems to pervade the whole. (116, 134, and 171.)

	Latitude.	Longitude.	Bar. range.		Latitude.	Longitude.	Bar. range.
Indian Key,	24° 48′ N.		.26 in.	Twinsburgh,	41° 18′ N.	81° 26′	.68 in.
Pensacola,	30 28	87° 12′	.46	New Haven,	41 18	72 58	.98
Natchez,	31 34	91 24	.79	New Bedford,	41 38	70 56	1.00
Savannah,	32 5	81 7	.65	Boston,	42 21	71 4	.92
Bermuda,	32 34	63 28	.41	Albany,	42 39	73 45	1.173
Lexington,	38 6	84 18	.96	Syracuse,	43 1	76 15	.95
Washington,	38 53	77 2	.98	Rochester,	43 8	77 51	1.03
Baltimore,	39 17	76 36	1.02	Hanover,	43 41	72 22	1.14
Marietta,	39 25	81 36	.98	Gardiner,	44 10	69 50	1.00
Springfield,	39 53	83 48	1.00	Halifax,	44 39	63 36	.52
Philadelphia,	39 57	75 11	.97	Montreal,	45 31	73 35	1.266
New York,	40 43	74 1	.97	Quebec,	46 49	71 16	1 57
Flushing,	40 45	73 52	1.042	St. Johns,	47 34	52 38	.85
Sunbury,	40 53	76 50	1.00				

I have copied from Professor Loomis a chart of the fluctuations of the barometer in this storm, and the reader will perceive that the minimum occurred every where on the same meridian, in the north, sooner than in the south, showing that the fluctuation travelled towards the east of south.



Professor Loomis says in regard to this table: "It will be observed that the range of the barometer increases generally with the latitude." This is one circumstance which renders it highly probable that the storm extended to a great distance farther north than the most northern observations. Another circumstance which favors this conclusion, and indeed renders it almost certain, is, that the wind every where changed round by the south to west and north west, as the storm passed on.

Professor Loomis thinks this storm moved towards the east. The barometric minimum, however, travelled from the W. N. W. to the E. S. E. and it is therefore highly probable, that the storm itself travelled in the same direction. Its velocity of motion in the middle States was about 25 or 30 miles an hour, for it moved from Springfield, Ohio, to Washington City in twelve hours, and to Philadelphia in fourteen hours.

Its motion seems to have been slower when it reached the British dominions, for it was twenty hours in passing from Quebec to Halifax, a distance of only about 400 miles. The mean velocity from W. N. W. to E. S. E. was not greater than 25 miles; and as the velocity of the N. W. wind was certainly not less than forty miles, from the manner in which it is generally characterized "violent gale," &c. it follows that much of this N. W. current rose on meeting the S. E. current in the middle of the storm; for if none of it had ascended, the storm would have moved towards the S. E. at least forty miles an hour. Professor Loomis's view, therefore, that the N. W. wind flowed under the S. E., is not entirely correct; for about one fourth as much of the N. W. current ascended as of the S. E., and on ascending it would spread outwards above from the expansion produced by the latent heat evolved during the formation of cloud; but it would be driven chiefly towards the eastward, or north eastward by the upper current of the atmosphere, which moves over the United States generally in that direction.

The barometer stood uncommonly high just before and just after this storm. On the 19th, at 2, P. M., the barometer at Philadelphia is marked, in my journal, maximum 30.73, and on the 22d, at 7, A. M., it had risen again to 30.61 — the minimum is not marked, but on 21st, at 7, A. M., it stood at 29.65. These maxima were produced by the outspreading of the air in the upper regions from the centre of the storm. The formation of cloud enough to make one inch of rain, would give out latent caloric sufficient to expand the air in the region where the cloud was formed, about one forty-eighth of its whole bulk, and cause the atmospheric column to be at least a mile higher in the centre of the storm than at some distance from its borders, provided the expansion took place only upwards: but this it could not do. Part of it would plainly spread outwards, and thus cause the barometer to rise on the outside of the cloud, at the same moment that it fell under the middle of it. A most conclusive proof that this was the case will be found in this: the barometer rose on the morning of the 19th, 0.08 of an inch at Philadelphia, from 30.65 to 30.73, and yet the wind at that time, in most of the eastern States, was westwardly, and at most of the western forts it was easterly; at Philadelphia it was nearly calm. Now these currents below, blowing both ways from Philadelphia, certainly tended to make the barometer fall there. The conclusion is, that the supply of air was from above.

As to the possibility of a storm passing the Rocky Mountains, perhaps Professor Loomis is correct in deciding that it could not. And yet a storm on the western side might probably be the means of generating one on the east side in the following manner. The latent caloric evolved by the condensing vapor of the storm on the west side, would cause a flood of air to swell up and roll over the mountain to the east. The first effect of this would be to raise the barometer on the east side. This would produce a western wind east of the mountain. The air, however, which crossed the mountain, containing in it the latent caloric which it had just received, being at least 30° hotter than air ordinarily is at that height, would not descend to the valley and be a "cold, dry" wind, as Professor Loomis thinks; it would indeed be dry, if it descended, but being warmer and lighter than the air through which it would have to pass, it would not descend; but flow off in all directions towards the east, the north, and the south. At the same time much of the air below would flow out in the same directions, and the effect of this would be to permit the whole upper stratum of air containing the latent caloric to descend to a lower level than it would otherwise have occupied. During this process the annulus of the storm would be extending further and further to the east of the mountain, causing a rise of the barometer under its pressure, and finally, on the ceasing of the storm on the west side of the mountains, the air at the surface of the earth within the annulus would be forced back towards the mountains; there it would ascend, and if it contained the suitable quantity of vapor, the process of cloud-forming would commence, and thus a new storm would be generated on the east side of the mountains.

If I have not expressed the principle very clearly how a storm on the west side of the Rocky Mountains would be the means of generating one on the east side, let any one consider for himself, what would be the result of a column of air being expanded by heat, on the west side of the mountains till it stood three or four miles higher, than a column on the east side, and he will perceive, by his own intellect, that there is some reason for the conclusion above.

He will readily see also, that a wind, blowing across the Rocky Mountains from west to east, producing rain on the west side, cannot become a "cold wind on the east."

He might indeed conclude, that it would produce no effect on the temperature at all, as it swims on the top of the atmosphere; but in this he would be wrong, for it would increase the temperature at the surface of the earth by its radiation. The efflux of air above, from the borders of a great storm-cloud, often produces an increase of temperature below by radiation, before the storm comes upon us, or any southern wind. It is a prevailing idea, that air does not radiate caloric. But this cannot be true; for it is the upper regions of the air, or at least a considerable distance above the surface of the earth, where the latent caloric of vapor is given out in the formation of clouds; a quantity sufficient, in many countries where sixty or eighty inches of rain fall, to heat it in one year six or eight hundred degrees. All this it must gradually part with, by radiation, after each successive rain.

It may, perhaps, be objected, that as the upper regions of the air, even in their warmest state, are much colder than the lower, they can never be said to warm the lower regions by their radiation; but this objection will vanish when we consider that the surface of the earth would become much colder in a given time by radiation, if it received no heat from the upper regions of the atmosphere, and from the celestial vault in the evening, when the sun's rays are withdrawn. M. Pouillet has made a most ingenious attempt by means of an Actionometer of his own invention, to ascertain approximately, the quantity of heat which is radiated from the upper regions of the air to the surface of the earth, and also, the quantity which is radiated from the fixed stars; and if his experiments do not settle the question, they at least prove, that the quantity of caloric, reaching the earth from those two sources is not inconsiderable, and also, that the upper regions of the air cool many degrees during the night, when they are receiving no heat from the sun. A wide field of investigation is here laid open to the future meteorologist; and I would recommend to every one who shall undertake to pursue this subject further, to observe the effect of the formation of dew on the actinometer, and also, to take into account the latent caloric received in the upper strata of the atmosphere during storms of rain and snow.

Much may be learned on this subject without an actinometer of M. Pouillet's construction, by a continued series of experiments of the following nature.

Place a thermometer on some bad conductor of caloric — the inside of a common washing tub, for example, whose bottom is covered three or four inches thick with straw, or charcoal, or wool, and expose the whole so arranged, on the ground under the open sky, free from the radiation of surrounding houses, and note from hour to hour every evening, the difference between this thermometer and one swung briskly in the air near the tub.[1] The more the thermometer at rest sinks below the one in motion, the colder will it indicate the upper regions of the atmosphere to be; except when dew is formed; when this takes place, the further depression of the thermometer at rest is greatly diminished by the evolution of latent caloric; and this will frequently happen, when there is no dew formed on the ground round about.[2]

May it not be possible that the approach of a distant storm might be discovered by this means?

The following article appeared in the Philadelphia Saturday Courier, of March 18th, 1837. Its value is much increased by Professor Loomis's investigation of the same storm.

Mr. Editor: — On reading in the London papers, recently arrived, the account of the remarkable snow storm that passed over England on the 24th, 25th, and 26th of December, my attention was recalled to some circumstances con-

[1] See Pouillet's Elements of Physics and Meteorology, third edition.

[2] If this plan is inconvenient, the thermometer may be laid on the grass, or on a board lying on the ground.

nected with the no less remarkable storm that traversed Pennsylvania on the evening of the 20th and morning of the 21st of the same month.

The approach of that storm was announced by the chairman of the Joint Committee on Meteorology of the Philosophical Society, and the Franklin Institute of Pennsylvania, at their session on Monday evening, the 19th December. The substance of Mr. Espy's communication was, that on a reference to the observations of Governeur Emerson, M. D., and his own, it appeared that the barometer had risen during the last twenty-four hours 1.05 of an inch; that it attained its maximum height at seven, P. M., and was then, at eight, P. M., beginning to descend; that such a rise of the barometer had not been observed in the same period of time for several years; that this and other phenomena noticed at the time induced him to think that we were then in the eastern part of the annulus or border of a violent storm; that though perfectly clear and calm at that time, it was reasonable to expect that the wind would set in from the east next morning; that in such a case it would be certain that in twenty-four hours, that is to say, by the evening of the 20th, the storm would reach this place, and would rage with a violence proportioned to the extraordinary rise of the barometer which preceded it; that the deposit of snow or rain, would, for the same reason, be very great.

For proof that the prediction was fully realized, I refer you to the account published in the journals of that date. The wind changed to the east next morning, the 20th, and the rain at this place, and snow further north, commenced falling on the evening of the same day, and closed on the morning of the 21st. Serious damage was done to the shipping in the Delaware, and at all our north eastern ports, and off the coast. At Buffalo, the wind drove a portion of the water of Lake Erie into the city, and it was stated in the gazettes of that date, that a building was set on fire at

Buffalo by the slacking of lime from water driven eastward by the force of the gale.

Dr. Franklin first ascertained that all storms travel towords the north east.

Mr. Espy's researches led him to believe that this constancy of direction in this locality is confined to our winter storms and summer tornadoes. He has also found from observations furnished by Professor Hamilton, that in the winter season, the rise of the barometer, as well as the presence of the centre of the storm, takes place at Nashville, Tennessee, about twenty-four hours earlier than at Philadelphia.

And here I would remark, that Dr. Emerson is the first observer, so far as my knowledge extends, who noticed that a great rise of the barometer is a prelude to a north easterly storm, a conclusion to which Mr. Espy has arrived, *a priori*, from his theory of storms. This conclusion is in direct opposition to popular opinion, and, indeed, to that of most philosophers, who have marked set fair on the barometer at one inch above the mean.

If I mistake not, Mr. Espy has some where stated in his lectures, that remarkable barometric fluctuations were often noticed to occur in the winter season about four or five days later at London than here, indicating that the centre of the storms to which these fluctuations owe their origin, traverse three thousand miles of a rhomb line on the earth's surface in that period of time, being at an average rate of about twenty-two miles per hour.

If the storm in Pennsylvania, of the 20th and 21st, followed such a course at that rate, the annulus or atmospheric wave which caused the remarkable rise of the barometer here, must have reached London about the 23d or 24th, and must have been the harbinger of the approaching storm at that place, the violence of which should be proportioned to the excess above the mean of the density of the atmospheric wave which preceded it. The storm lasted one day at this place, and three days at London, showing that its linear dimensions were three times as great there as here. The middle of the storm, or time of greatest depression of the barometer, was during the forenoon of the 20th, and should have been on the 25th or 26th at London, if these two storms were the same. Take from this date a day and a half for the semi-duration, and twenty-four hours for the period which the point of greatest atmospheric density preceded the beginning of the snow, and we have the 23d for the date of the greatest rise of the barometer at London, according to Mr. Espy's theory.

Whether such a rise and depression of the barometer was observed in London, or not, remains to be learned. It is by no means improbable, however, that if observations in the whole intermediate space on our northern coast, and on the Atlantic ocean, could be obtained, the remarkable storm of the 25th and 26th of December, would be found to be the same, which did so much harm to the shipping in our ports, and off our coast, on the night of the 20th, and the morning of the 21st.

Should such be found to be the case, it will then be an important subject of inquiry, whether the unusual retardation of our homeward bound vessels from Europe in December, and the lateness of their arrival in January, after a passage of forty, and sometimes fifty days, and, in short, whether the appalling losses sustained by our insurance offices at that period, were not, in some degree, owing to their track being crossed by this violent storm, whose width in the direction of their course, must have been near fifteen hundred miles. Should such a circumstance be shown to be probable, then would the occurrence of similar meteorological phenomena in the winter months on land, be regarded as the prelude to similar disasters at sea, the foresight of the merchant and underwriter, and the protecting hand of government, would be directed to the means of affording relief to those vessels and crews at sea, which may be presumed to be in distress from the perils which it is known they must have encountered.

My motive in making this public testimonial of the correctness of Mr. Espy's announcement on the 19th of December, as a practical illustration of his theory has been, to suggest the propriety of concert among observers in this important department of science, for the purpose of learning more fully the course of storms and tornadoes, in traversing the earth's surface.

Many observations important to pilots and navigators might be elicited, on a subject in which every step of advancement made, and every peril removed or obviated, is fraught with the happiest consequences to society.

While engaged on this subject, it is proper to mention, that a valuable contribution to the science of meteorology, is contained in a memoir on "the Gales and Hurricanes of the Western Atlantic," published last summer, by Mr. W. C. Redfield, in the transactions of the Naval Lyceum.

Yours, truly, S. C. WALKER.

P. S. Since writing the above, I have been favored by Dr. Emerson, with the perusal of a letter addressed to him by his correspondent, Mr. Gardiner, of Gardiner, Maine, which states that the barometer attained its maximum height in the afternoon of the 20th, and its minimum at five, P. M., of the 21st; that there was a violent gale at seven, A. M., of the 21st, and that the rain commenced at ten, P. M., same day. Thus the principal phases of this storm at Gardiner, Maine, occurred almost a day later than here, and they furnish a link in the chain of evidence required to warrant a just and definite conclusion, concerning the identity of these two storms. S. C. W.

SECTION SIXTH.

BRITISH STORMS.

Great Liverpool Storm of 6th and 7th of January, 1839.

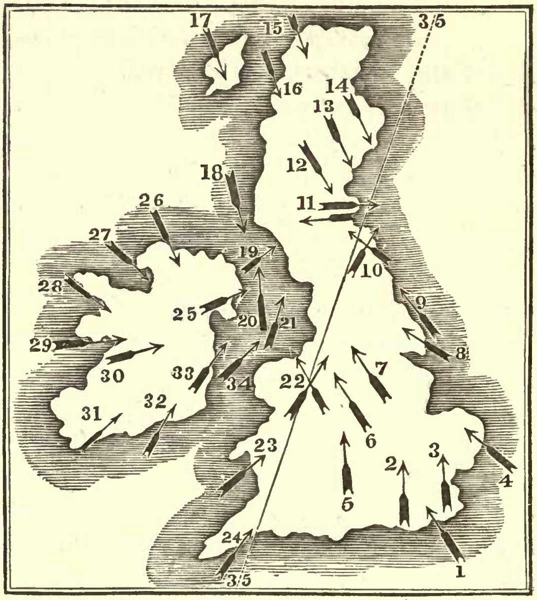
171. This storm, which proved so destructive to life and property, excited a great deal of interest at the time, and I was very desirous to collect authentic documents concerning the phenomena which attended it. Having failed to obtain sufficient data while in this country to enable me to determine its *modus operandi*, I availed myself of the opportunity, which my visit to Europe in 1840 afforded me, to collect further information on the subject; and the penny post then enabled me to do so without much expense — a burden which I find intolerable in this country. I have embodied all the documents in the Appendix, which I have been able to collect, and to aid the reader to understand the matter at a glance, I have exhibited the information concerning the winds, on the accompanying chart, with arrows, numbered, and a corresponding brief account of the place and direction of the wind between 10 and 12 o'clock on the night of the 6th. At this time the central line of the storm extended through the middle of England, from N. N. E. to S. S. W., reaching to an unknown distance on the north and south, and from the western coast of Ireland to the eastern coast of Great Britain. The storm certainly extended on the north to Sumburg Head, Orkney, as the barometer there fell to 27.25 at 2, P. M. of the 7th, and as the

wind set in there on the 6th, as it did all over England, from the south east, it is quite probable that Orkney was south of the middle of the storm. The greatest violence of this storm, however, was felt through Ireland and the middle of Great Britain, as it passed from west to east, or probably a little to the south of east. Indeed it is almost certain, that the storm moved towards the south of east, if the indications of the barometer are to be relied on, for this instrument fell progressively from north of west to south of east. And this accords with what I have remarked in many other great fluctuations. Indeed, so uniformly has this been the case, whenever I have had an opportunity of examining documents, that I am inclined to think it is a general rule in this latitude.

By casting the eye on the chart, the reader will perceive there is a general tendency of the wind on the south east of a line drawn through the middle of Great Britain, from Plymouth on the south west, through Edinburgh, towards that line from the south of east, and on the western side of that line there is a general tendency of the wind towards the line from the west and north west, especially at remote distances from the line, whilst near the central line there is more irregularity.

By examining all the documents, the reader will also learn, that there was a considerable fall of snow and rain near the middle of Great Britain on the 5th and 6th; which no doubt was the beginning of this storm, and caused it to be more violent in this region than it was farther north and farther south. The wind also sprung up fresh and strong, on the 6th, from the south of east in the southern parts of Great Britain and Ireland, about the time that it changed round in the west of Ireland, and began to blow a gale from the west; and for many hours, in the early part of the night, it was increasing on the eastern coast of England, from the east of south, and at the same time, on the west of Ireland, it was increasing to a hurricane from the west; on the south west of Ireland, from the south west; and on the north west of Ireland, from the north of west and north west.

Chart, showing the course of the Wind in Great Britain and Ireland, on the night of the 6th of January, 1839, between 10 and 12 o'clock.



No.
1. Romney. Strong S. E. at 8, P. M.
2. London. Southward all night; violent.
3. Thwaite. Strong S. S. E. from 10 to 12. (O. Whistlecraft.)
4. Sou hwald. The Susanna driven on shore by a S. E. wind at 8, P. M.
5. Birmingham. Wind east of south, strong till 1, A. M., then strong west of south. (Osler's Anemometic.)
6. Manchester. S. E. till midnight, very strong. (Narrative, p. 24.)
7. Leeds. S. E. till midnight, very strong, then S. W. (Leeds Intelligencer of 12th)
8. Bridlington. Got round to S. E. in the night, and continued so blowing a gale till midnight.
9. Whitby. S. by E., high wind at 10½. (Henry Belcher.)
10. Berwick. Changed from east of south to S. W. at 10, P. M.
11. Edinburgh. Changed in the night from east, strong and cold, to the west. (Edinburgh Advertiser of Jan. 8.)
12. Dundee. On the night of the 6th and day of 7th, N. W. (S. M. G. of 10th.*)
13. Montrose. On night of 6th and day of 7th, hurricane. W. N. W.
14. Aberdeen. N. W. and N. N. W. (G. Innes.)
15. Cape Wrath. All 6th and 7th, N. W.
16. Scowrie. Evening of 6th, till 12, N. W. (G. Ross.)
17. Isle of Glass. At 11, P. M., N. W., Lighthouse.
18. Lismore. On night of 6th, N. W. to N. Lighthouse.
19. Corsewell. S. W. from 6, P. M. till 12. Lighthouse.
20. Mull of Galloway. S. till 1½, A. M. of 7th. Lighthouse.

* S. M. G. means Shipping and Mercantile Gazette.

21. Calf of Man. S. S. W. till midnight. Lighthouse.
22. Liverpool. Changed from S. S. E., with a calm, to S. W., between 11 and 12; strong before change, violent after. (Times of 13th.)
23. Swansea. Changed in the night from east of S. to S. W.
24. Plymouth. S. W. till 12, strong.
25. Strangford. W. S. W. at midnight. (S. M. G. of 11th.)
26. Londonderry. N. W. at 11, P. M. (S. M. G. of 11th.)
27. Sligo. W. N. W. in the night.
28. Newport. W. N. W., in the night a hurricane. (S. M. G. of 10th.)
29. Kilrush. At 10, P. M., a complete gale from the west, increasing till $1\frac{1}{2}$, A.M., then violent W. S. W. Wm. Monday.
30. Adare, near Limerick. Clear, and heavy gale from the westward at 9, P. M. increasing till midnight, then tremendous hurricane; wind commenced about 4, P. M., W. S. W., having been S. S. E. in morning. The clouds came fast from W. S. W. before the wind commenced.
31. Cork. Westerly at 8, P. M., and very strong at 9.
32. Waterford. S. W. early in evening.
33. Ship Doterel, at Kingston, near Dublin. Fresh gales, and cloudy; S. W. at 8, P. M.
34. Ship Doterel, on her way to Liverpool. Heavy gales and thick rain, S. W. from 10 till 2, then W. S. W., a hurricane. Very hard gale still between 6 and 8, of 7th. W. N. W.
35. Central line of the storm at 11, P. M., of 6th. This central line moved towards the E. or S. E. On next day the wind was westerly all over the British Islands, N. W. in Scotland, and S. W. in the south of England.

At this same time, the wind in some parts of the west of England, at Liverpool, for instance, suddenly ceased to blow from the south of east, and after a short calm, came out westwardly, with unspeakable fury. At this time also, the barometer was falling very rapidly, and though it was clear in the west of Ireland, immense quantities of rain were falling near the middle of Great Britain and Ireland. The barometer, however, began to rise in the western parts of Ireland, while it was yet falling with great rapidity in England, and its greatest depression at London did not take place till many hours after it occurred in Ireland and even in Scotland.

In one place, however, where the island is very narrow, the lowest depression of the barometer seems to have taken place at the same time on the east and west coast — at Edinburgh and Glasgow; and it is worthy of particular remark, that it was in this region, where peculiarly large quantities of snow and rain had been falling for two or three days. And this seems to account for the gathering in of the winds on the 6th towards this region, both from the south east and north west of Great Britain. It is true, that the wind at several points on the eastern coast of Britain, was north westerly on the morning of the 6th, and at the Fern Islands, near the eastern coast, it blew a hurricane from the north west. Yet this renders it more remarkable, that the wind should change round in the evening to the east at Edinburgh, and south of east at various places on the east coast of England, to meet a mighty hurricane of wind and rain from the west and north west, which, at that very time, was increasing in violence on the western coast.

The careful reader will find many irregularities, some of which, no doubt, depend on the dates not being exact, and some accidental, as at Pladda, the barometer is stated to be at its minimum at four, P. M., of 7th, when, no doubt, it ought to be four, A. M.

But great irregularities would be produced by the renewal of the storm in the north of Scotland, as fully appears by the account at Dunnet Head, where the barometer, which had risen on the 7th, from 27.35 to 27.98, began to fall again about midnight, and fell by three, A. M., of 8th, to 27.65, with a complete hurricane from the west, and it continued a hard gale all the 8th, and most of the 9th, from the north west.

This renewal of the storm, on the night of the 7th, reminds us of the storm of the 15th December, 1839, in the United States, which was renewed on the next day.

It is also particularly worthy of remark, that the barometer exhibited a gradual increase of depression on the night of the 6th, all the way from London, along the eastern coast of Great Britain. It was not lower than 29.00, at London; at Whitby, it fell to 28.40, at eight, A. M., of 7th; at Dunnet Head, in north east of Scotland, it fell to 27.35, at seven, A. M., of 7th; and, at the same time, the wind on the whole southern part of the island, was blowing towards the north, where the barometer was very low.

172. It would be highly interesting to know where this storm originated. It certainly existed, though perhaps with less violence, west of the British islands on the 6th.

There had been rain or snow every day from the 1st of the month, at Glasgow, with the wind westerly, and yet on the evening of the 6th, the wind changed round to south east, notwithstanding the tendency of the wind to blow from the west after a rainy spell of weather. In Ireland, too, the wind changed round to south east; and in one instance, Newry, to the north east, and blew hard at the beginning of the storm. So says the Drogheda Journal of January 8th. This, probably, should be south east. And yet if there was at that time an uncommon violence of upward motion in the air south west of Newry, the effect would be a violent north east wind at Newry.

At Drogheda, the storm arose about 11, P. M., south east, with terrific and unprecedented violence. It seems probable that this is too late an hour for the south east wind to be blowing; for at this time, according to numerous accounts, the wind in that part of Ireland was at that time from the south west. Be this as it may, the very fact of the wind every where changing round from west and north west on the 6th in the morning, to south of east in the day and evening, is a proof that there was a storm of some violence approaching from the west or north west.

In fact, the Guiana experienced a dreadful hurricane nine miles from Cape Clear, the south west of Ireland, and there are other accounts of ships laboring in a gale, still further west, on that day.

There are two reasons why the wind from the eastward at the beginning of the gale, should not be as strong as the wind from the westward at the end. First, the west wind is the natural wind of the climate in Great Britain, and this would tend to diminish its force from the east and increase it from the west. In the second place, the storm was greatly increased in violence on reaching the British islands, and, therefore, on passing off to the east, the violence of the west wind would be greatly augmented in pursuing it.

Finally, even if I had not been so fortunate as to collect any information that the wind sprung up from the eastward to meet the approaching storm, the simple fact that the storm began violently from the westward, in Ireland, six or seven hours sooner than it did on the eastern coast of Great Britain, would be sufficient to prove that there must have been an upmoving current of air between those two places, and that too a very violent one, more especially as there was a tendency inwards from the south west, on the south of Ireland, and also a tendency inwards from the north west on the north of Ireland; therefore, as it did not blow out at the sides, it must have ascended in the middle, and thus all the process of cloud-forming, &c., by the cold of diminished pressure, would be produced.

Indeed, it must be so, whenever the wind blows with violence, or even moderation. There must be an upward motion somewhere, unless the wind blows all round the world in that direction, or sweeps off in a circle or out at the sides.

In concluding these remarks, I beg the reader to examine the documents for himself, and he will find many circumstances, not noticed here, confirming the doctrine that the wind blows inwards on all sides towards the centre of storms. And especially let him ask himself the reason why, on the next day when the storm had passed off with its centre to the east of Great Britain, the wind on the south of England was blowing hard all day from the south west, and in Scotland from the north west, if the doctrine here taught is not true? [For original documents see Appendix.]

Storm of 17th August, 1840.

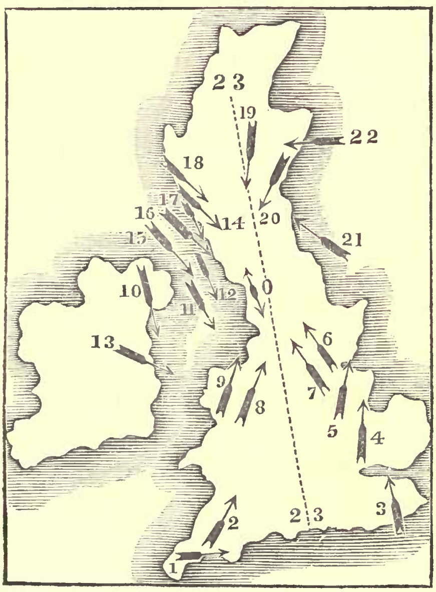
173. While I was in England, in the summer of 1840, a storm of some interest occurred, especially as it was desirable to know how to compare the phenomena of a summer

storm with the one in the winter of 1839, which has just been investigated.

All the documents which I could obtain, not only in the region of the storm and in its borders, but to a great distance beyond, are given in the Appendix. It will be seen by a reference to them, that a vast quantity of rain fell in the region between Lismore light house and Leeds; for at the Mull of Galloway, more than two inches and a half fell and at Pladda light house, more than two inches, and all the rivers in that region, the Ayr and the Irwell for instance, were raised to an almost unprecedented height.

It is true, there were great rains all over the United Kingdom at this time, but nothing to compare with what fell in this quarter.

Chart showing the course of the wind on the morning of the 17th August.



0. Workington, changed at 10, A. M., from S. S. E. to N. N. W.
1. Plymouth, W. on 17th, S. W. on 16th.
2. Pill-Bristol, S. W., A. M.
3. London, southwardly, on 17th.
4. Lynn, heavy S. till noon, then S. W., more moderate.
5. Hull, S. S. W., strong.
6. Leeds, S. E. or S. S E., strong from 8, A. M., to 1, P. M., clouds at this time moving from S. W.
7. Sheffield, S. S. E. all day, next day, E. Strong on 17th.

8. Hyde, near Manchester, S. W., in the morning; west in P. M.; strong gale all day,
9. Liverpool, S. W., A. M., N. Westerly, P. M., strong.
10. Belfast, N. by W. strong gale.
11. Point of Ayre Light, N. W. gale.
12. Corsewell Light, N. N. W., storm.
13. Dublin, W. N. W.
14. Largs, heavy from N. N. W. from 7, A. M. till 8, P. M.
15. Kyntire Light, N. W. gale.
16. Pladda Light, N. W. breeze.
17. Greenock, N. W. and N.
18. Lismore Light, N. W. gale.
19. Dumferline, N. and N. E. till 2, P. M. increasing to a gale.
20. Edinburgh, N. N. E. strong.
21. Berwick, S. by E. to S. E., strong.
22. Aberdeen, E. all day, strong.
23. Middle line of the storm on morning of 17th.

Now if the reader will cast his eye on the chart he will perceive that there is a tendency of the wind in all the borders of this great rain to blow inwards to the region where the greatest quantity was falling. At greater distances from this region, at Plymouth and London, for instance, there is much deviation; but as considerable rain fell in these localities, such irregularities are to be expected. Indeed the evidence of the inward tendency of the wind towards great rains, is very strong in this storm when we see it overcome all irregular winds around its borders, whilst those at a considerable distance from its borders, seem but little affected. It seems probable that this storm moved down towards the south east or S. S. E.; for it began in Scotland, at the head waters of the Tay, in the north west of Perthshire, before it did at Perth in the south east of that shire, and at all the northern light houses there was rain on the 16th. At this time the weather was fine at Leeds. In the afternoon, however, the observer, Mr. Marshall, says, a middle current commenced from the south east, and afterwards, on the next morning, the wind below changed round to the same direction.

174. It is worthy of particular remark that on the 16th, when there was a great rain in the middle of Scotland, the wind at all the light houses on the south west of Scotland was from the south west; at some of them a gale, and at Edinburgh it was south, increasing to a strong wind in P. M., then dying away and afterwards springing up strong next morning N. N. E. at which time it had begun to rain violently in a large tract south west of Edinburgh.

This circumstance is more remarkable in connection with the fact, that about the very time the wind sprung up strong from the N. N. E. at Edinburgh, it sprung up violent from N. N. W. at Largs, near Glasgow, in the west of Scotland. At this time, also, the wind at all the light houses in the west of Scotland is given north westerly.

It is quite certain from all these facts, that the centre of the storm passed down from Scotland into England between Edinburgh and Largs, a town on the west side of Scotland, near Glasgow; and all this time as the storm was passing, the wind at Berwick and North Shields, near Newcastle, on the east coast of England was changing round from south by east to north east and at all the light houses in the south west of Scotland, the wind, which had been south west before, changed round to north west.

I have an account also in a paper, name not known, that the wind changed round suddenly at Workington, about the centre of the region towards which the wind was blowing at ten, A. M., attended with violent rain. The barometer fell more than an inch, as the reader will perceive, by examining the documents, and stood much lower near the region where the great rain fell than it did at Belfast, Cape Wrath and Aberdeen.

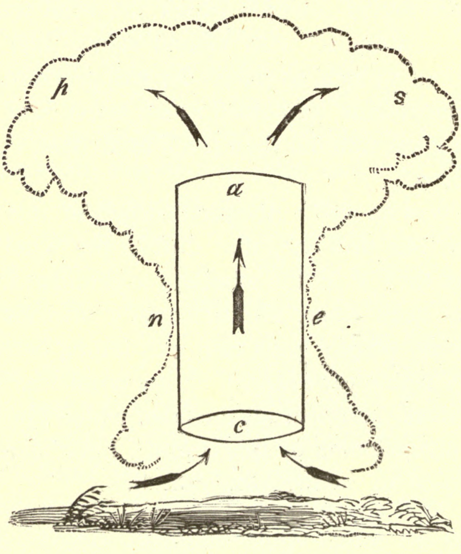
If there was no well authenticated fact in this whole investigation, but this one, that during the whole morning from 8 A. M. till 1, P. M. the wind at Largs and at Leeds, were blowing at each place, almost exactly towards the other with violence, while a great rain was falling between them, in the very region towards which the wind was blowing, it would, of itself, be worth all the labor which I have expended in the investigation of this storm. Let the reader carefully examine all the facts for himself.

SECTION SEVENTH.

OF THE TORNADO OR WATER-SPOUT.

Lemma.

175. Suppose a receiver, only a few hundred yards in diameter, but so lofty that its top would reach to where the barometer would stand at 10 inches, and that it contained



air about $25\frac{1}{4}°$, for example, hotter than the air on the outside, this latter being at a mean, 32°. The column of air then in the inside of the receiver would be expanded $\frac{25.25}{505.25}$ of the whole, or one-twentieth of the whole bulk. Now as the air on the outside of the receiver, from the surface of the earth to the top of the receiver, weighs 20 inches of mercury, the air on the inside will weigh only 19 inches of mercury, and of course it will be pressed upwards against the upper end of the receiver at *a*, with a force of about half a pound on the square inch, the bottom of the receiver being open at *c*.

Also, if a barometer should be placed in the inside of the receiver at the top *a*, it would stand an inch higher than one on the outside at the same height; therefore if a small hole should be made in the top of the receiver the air would spout out with a velocity due to a head of pressure equal to one inch of mercury. This is equal in weight to about 900 feet of air of mean density at the earth's surface. The velocity with which it would spout on supposition of its having this density will be found by the common formula for spouting fluids $8\sqrt{900} = 240$ feet per second. But the air at the top of the receiver is only about one third the density of that at the surface of the earth, provided no allowance is made for temperature; and as the velocity of spouting fluids under equal pressure is inversely as the square root of their densities, the real velocity with which the air will spout out at the top of the receiver will be $240 \times \sqrt{3} = 415$ feet per second.

If now we suppose the whole top of the receiver to be taken off, the velocity will be the same, if there is no friction up the sides of the receiver, and the air gets freely in at the bottom, an allowance of course being made for the reaction of the air in the upper part of the receiver on the air below, in consequence of the velocity increasing all the way up.

This is a case, however, which could not occur, for there would be friction, and the present state of science does not enable us to estimate its amount.

If, however, we place our barometer in the lower end of the receiver, and ascertain its fall there, it will give us the actual velocity of the air upwards, free from friction, and from the reaction of the air downwards, as it increases in velocity in its upward motion. And in this case, too, the power of the air to carry up heavy bodies will be the same in every part of the receiver, if it is cylindrical, for the velocity increases in exact proportion to its rarefaction. For example, if the barometer falls an inch on being placed in the receiver at its base, the air will rush up there with a velocity of 240 feet a second, and at the top of the receiver, being only one-third the specific gravity which it had below, it will move with three times that velocity, or 720 feet per second. Now this velocity would be sufficient to carry up heavy bodies of considerable size, and throw them out at the top of the receiver, masses of ice, for instance, as large as a man's head.

If, however, we conceive holes of considerable magnitude made in the sides of the receiver, at some distance from its top, it will be manifest, that bodies might be carried up to these holes, which could not be carried up beyond them; for so much of the air would escape through these holes, that the velocity of the current above them would be much diminished. And thus these masses might play about near these holes, without ascending much above them, or descending much below them. Moreover, if the masses should increase so much in number or size that the current of air even below the holes could no longer sustain them, they would begin to descend; and if their cooling effect on the air below should be very great, they might, partly by their weight, and partly by their cooling influence, change the current, and cause it to move downwards and outwards below.

During this operation the barometer at *a* would stand a little higher than one on the same horizontal level at some distance from the upmoving current, notwithstanding it is in the midst of an upmoving current, which, it is generally supposed, has a tendency to cause a fall in the barometer. At the surface of the earth, the fall of the barometer, and an upmoving current of air, are simultaneous effects of the same cause, a diminution of weight of the whole column of atmosphere to the top; but the quantity of atmosphere over *a* will be greater because it is swelled up over *a* to the very top of the atmosphere, and of course runs outwards in all directions from *a*.

Again, if, instead of making holes in the receiver, we remove the entire sides, it is manifest that the heated column of air, which we suppose to be the same as before, would spread out laterally in ascending, in the form of an inverted cone, or mushroom, as exhibited by the dotted lines *p*, *s*, *n*, *e*. And this spreading out would take place sooner, and be more flaring, if heavy bodies were carried up in the middle of the ascending column. But still, as long as the barometer indicated a depression of one inch in the middle of the base of the upmoving column, the velocity with which the air would move upwards there would be 240 feet per second.

When the air near the surface of the earth becomes very much heated or very highly charged with aqueous vapor, such an ascending column as is here imagined may actually take place, and be kept up for a long time. The difference of temperature of the ascending column and that of the atmosphere through which it passes may be much greater than that here supposed, partly caused by its greater temperature below; but chiefly from the great quantity of latent caloric evolved by the condensation of vapor into cloud.

It becomes then a matter of high interest to calculate the shape of such an ascending current, and its specific gravity when compared to that of the surrounding air through which it passes, and thus to know how much the barometer will fall under the centre of the ascending column, and how much it will rise all round the column by the rapid outspreading of the air above. Data for making these several calculations are known proximately, and may be stated very briefly as follows.

1. The decrease of temperature in ascending in the atmosphere.

2. The diminution of pressure which the ascending current experiences at all heights in its ascent.

3. The degree of cold produced by that diminished pressure.

4. The quantity of vapor in the air at the surface of the earth, from which the upmoving column is supplied.

5. The number of degrees the dew point is below the temperature of the air at the time.

6. The height to which the air will ascend before it begins to form cloud from the cold of diminished pressure.

7. The quantity of vapor which will be condensed by this cold, at all heights to which the current ascends.

8. The quantity of latent caloric of *elasticity* evolved by the vapor thus condensed.

9. The quantity of latent caloric of *fluidity* evolved by the vapor thus condensed in case of hail or snow.

10. The specific caloric of air at different densities.

11. The number of degrees the air would be heated, or rather prevented from being cooled, in its upward motion, by the caloric of elasticity, and caloric of fluidity thus given out.

12. The diminution of the specific gravity of the air in the cloud, produced by the evolution of this latent caloric.

13. The height to which the air will ascend before all the vapor is condensed which can be condensed by the cold of diminished pressure.

14. The quantity of space left unoccupied by the con-

densed vapor, and the increase of the specific gravity of the cloud on that account.

15. The diminution of specific gravity in the cloud, on account of the higher dew point there than in the surrounding air.

16. The increase of the specific gravity of the cloud from the quantity of water it contains, formed out of the condensed vapor.

From these data, a general formula for the specific gravity of any cloud formed under given circumstances may be investigated, and the dynamics of the air may thus be brought under the dominion of mathematics. The problem is commended to the notice of the profound analysts.

This lemma will enable the reader to understand the manner in which I conceive the air to rise in tornadoes or water spouts, which I now proceed to investigate.

The Brunswick Land Spout.

176. In perusing the phenomena attending this tornado or land spout, let the reader bear in mind the following principles, and he will have no difficulty in understanding not only all the facts detailed, but *how* the mighty power was generated, and continued so long undiminished, notwithstanding the amazing resistance to the motion of the air at the surface of the earth presented at every moment by the trees and houses overturned.

The reader will find abundant proof in the subsequent details that the air went up in the middle of the spout with great velocity. Now, air cannot go up without expanding from diminished pressure; it cannot expand without becoming colder; it cannot sink in temperature below the dew point without condensing some of its vapor; it cannot condense its vapor without giving out the caloric of elasticity; it cannot give out the caloric of elasticity without expanding the air in which the vapor is condensed into water, about seven thousand cubic feet for every cubic foot of water thus generated. And if the drops of rain are congealed, the caloric of fluidity evolved will expand the air about one thousand cubic feet more. Thus an upmoving column of air mingled with vapor becomes a mighty steam power, which may be calculated like any other steam power, if the tension of steam in the atmosphere, and the height of the cloud from its base is given; for these two being given, the quantity of vapor condensed can be calculated.

I have not been able to learn what the dew point was at Brunswick, on the day of the spout, but at Philadelphia it was 71°, and the temperature of the air was 82° at three o'clock.

If we assume that the dew point at the spout was 71°, and the temperature of the air 79°, from the principles explained, when the air at the surface of the earth first commenced its motion upwards in the form of a column, it would have to rise eight hundred yards before the upper end would, by the cold of expansion, begin to condense its vapor into cloud. And this would be the height of the base of the cloud to which the spout belonged, at the moment of its first formation.

But as the cloud increased in height above, the air below the cloud would be pressed less and less by the superincumbent weight, and thus the air at the surface of the earth would begin to condense its vapor before it ascended eight hundred yards, and, therefore, the base of the cloud would seem to descend. And if the cloud above became so lofty and so light that the barometer sunk two inches underneath it, the visible spout or cloud would reach the earth; the air under the cloud would be cooled 8°, by expansion. And inversely as the cloud in this case did reach the earth, the barometer did fall two inches. Two inches of mercury is equal to about eighteen hundred feet of air in perpendicular height, and this is the diminished head of pressure in the inside of the spout at the surface of the earth; and it is known by mechanics, that the velocity of the air in the spout upwards, would, in this case, be $\sqrt{1800} \times 8 = 340$ feet per second, or about one pound on the under surface of bodies carried up, per square inch. Indeed, the force would be something greater than this, because the barometer would rise a little above the mean, at some distance from the spout, on account of the outspreading of the air above in an annulus, and thus increase the quantity of gravitating matter at a small distance from the spout — a distance which I am not able at present to calculate, but evidently not great, as there is known to be a calm all round a tornado, within a few hundred yards.

The reader will now be able easily to comprehend all the *facts* about to be detailed, and also perceive that they are a true *experimentum crucis*, to prove the truth of the theory advocated in this work.

I should long ere this, have laid these facts, so far as collected by me, before the public; but they are so remarkable and so conclusive in favor of my theory, that I feared there might be some suspicion excited in the mind of the reader, that they were colored to suit my own views. This evil I knew could be entirely avoided, by waiting till Professors Johnson, Henry and Bache, should hand in their testimony, which I knew would be perfectly conclusive on the subject.

The following is an extract of a paper read by Professor W. R. Johnson, before the Academy of Natural Sciences of Philadelphia, on the 21st February, 1837.

176. *a.* Considered as a meteorological phenomenon, the calamity which, on the 19th of June, 1835, desolated a part of the city of New Brunswick, in New Jersey, is worthy of the most attentive investigation. In connection with the accompanying sudden, and singular changes of temperature, and moisture in the air, it may serve to illustrate the

causes of those occurrences which, sometimes in our own climate — and more frequently in tropical regions — display effects which have hitherto perplexed the minds of the most acute observers. All accounts concur in representing the air of the morning, and indeed of the whole day up to the time of the tornado, as unusually sultry. This was observed between the hours of two and four, P. M., in a ride from Hightstown to Princeton, a distance of about nine miles; also, in the city of New York, and on the voyage from the latter city to New Brunswick. At four o'clock, the sun was still unobscured at Princeton; but within half an hour, a cloud from the north west had reached that place, and a shower of rain, accompanied by a brisk wind from the south west, had commenced. Before five o'clock, the rain had ceased, and the air was less oppressive. The evening continued tranquil until ten o'clock, when another shower of rain fell, accompanied by some wind; but within half an hour, the sky was once more cloudless, and the wind began to rise with much force, from the west or north west, and from twelve at night to five next morning, it was boisterous.

Intelligence of the occurrences at New Brunswick having been received during the forenoon, it was resolved to visit the spot, and endeavor to ascertain, by observation and inquiry, while the traces were yet unobliterated, such facts as might explain the mode of action by which the devastation had been effected. On arriving within six miles of New Brunswick, on the old turnpike road, we[1] were informed by an eye-witness, that it had been seen about a mile and a half north easterly from that point; and that the dense black cloud was, by the junior observers, conceived

[1] In this excursion, and the subsequent inquiries, the writer was accompanied and aided by his friend Professor Joseph Henry; who is to be considered as entitled to a full share of whatever credit may attach to the observations referred to in this paper.

to be *filled with crows*, — an appearance afterwards explained by the fact that shingles, boards, &c., had been carried upward by the tempest from buildings destroyed in that vicinity.

On reaching the height of land, at about half a mile from the dense portion of the city, the first buildings which had been damaged by the tornado were passed. A barn had been completely demolished, and most of the lighter materials scattered to a great distance. The house was not thrown down, but left leaning, with no part of the roof remaining, except some of the rafters; and the fact here witnessed was repeatedly observed in the town below, where several houses, within the path of the tornado, were deprived of their shingles, and the ribs which had held them to the rafters; but the latter still continued partially or entirely undisturbed. In a few cases, in which the ridge of a building lay in a northerly and southerly position, the eastern slope of roof was observed to be removed, or at least stripped of its shingles, while the western slope remained entire. Many buildings were likewise observed with holes in their roofs, whether shingled or tiled, but otherwise not much damaged, unless by the demolition of windows. These appearances clearly demonstrated the strong *upward* tendency of the forces by which they were produced, while the half unroofed houses, already mentioned, prove that the resultant of all the forces in action at the moment was not in a perpendicular to the horizon, but inclined to the east. Such a force would apply to the western slope of the roof some counteracting tendency, or relieve it from some portion of the upward pressure. Had there been no other facts to show the powerful rushing of currents upward, the above would, it is conceived, have been sufficient to settle the question, but taken in connection with the circumstance that roofs so removed, were carried to a great height, and their fragments distributed over a large extent along the subsequent path of the storm, that beds and other furniture were taken out of the upper stories of unroofed houses, that persons were lifted from their feet or dashed *upward* against walls; and that in one instance, a lad of eight or nine years old, was carried upward and onward with the wind, a distance of several hundred yards; and particularly that he afterwards descended in safety, being prevented from a violent fall by the upward forces, within the range of which he still continued. In connection with these and similar facts, it seems impossible to doubt that the greatest violence of action was in an upward and easterly direction.

The next point to which attention was called by the appearances around, was the manner in which this upward current had been supplied from below; and for the solution of this question, it was necessary to compare objects throughout the whole breadth of the track left by the storm. Apeach orchard, on the slope of the hill descending to the town, gave the first indication in regard to this matter, but the larger fruit and ornamental trees, in the gardens of Dr. Janeway, Messrs. Kirkpatrick and others, in the same neighborhood, together with an inspection of the forest on the east side of the river, showed conclusively that on the extreme borders of the track the forces were nearly, or quite at right angles to its general direction. Uprooted trees along the southern border lay with their tops towards the north; those on the northern border to the south, thus pointing to a common object in the central line of the current. From the outer edges, however, toward this central line, the trees were observed on both sides to have a gradually increasing inclination towards the east, and in the middle to be entirely in *that*, as a general direction. I do not recollect to have encountered a single case in which the top of a tree, *with its roots in the ground*, was lying towards the west, though I cannot say that none occurred, for among the houses and other obstacles within the city, presenting different degrees of resistance to the lateral currents, there may very probably be some points in which great violence was exerted in directions varying from the general course of action. None were seen with the tops from the centre of the path. Another fact to this point is, that Dr. Janeway's barn, a frame building, which was on the southerly part of the track, was unroofed, and the remaining part of the structure, with its contents, removed bodily three or four feet to the *northward.* All the herbage, shrubs and trees in its immediate vicinity, and the trees of Kirkpatrick's garden, were found lying with their heads in a northerly or northeasterly direction. Similar to the case of the barn just mentioned, was that of Bishop's store, near the river, which, standing on the northern border, had been lifted from its foundation about four or five feet towards the south. A row of poplar trees which had been prostrated in the lower part of the city, and on the *northern* part of the path was observed as a striking exemplification of the application of lateral force, every tree taking in its fall a southerly direction. Another evidence of lateral inward currents, was found in the appearance of many forest trees, east of the river, which, though too far removed from the central line of the path to be uprooted, were still so much within the range of the lateral forces as to have their outside limbs, or those most remote from the central line, broken off by the effect of cross strain; while no similar fracture was seen on limbs turned towards the centre of the path. This result will be easily understood, when we consider the well known difference between breaking a limb by cross strain and that of drawing it asunder by simple longitudinal tension.

Another fact indicative of the direction of currents from the sides inward, was noticed on the plain, east of the Raritan, where the fragments of boards, shingles, ribs, &c., which had been brought from houses demolished in the city, were seen to be arranged on the ground with some irregularity, certainly, but with far greater conformity of position than we could have anticipated. Their longitudinal direction was generally towards the central line, and also towards the point to which the storm was moving. Many of these were found far beyond the belt of ground on which the violence of the wind had been exerted. Their position may be explained by referring to the three forces in action at the moment they reached the ground: — first, the force of gravity, which, if the air had been motionless, and the bodies descending perpendicularly, would probably — from the unequal density of the parts of the several masses — have caused most of them to descend endwise; and then the position, subsequently taken by them respectively, would have been a matter of indifference, and we might have expected to find them lying promiscuously. But, second, they were, while in the air, moving onward with the storm in an easterly direction, and when the lower end struck the ground, the composition of this force with gravity, would naturally have thrown the centre of gravity over to the *east*, and we should have expected to find the lighter end of every piece of timber in that direction. But, third, if a current of wind were encountered near the ground, running towards the centre of the path, we should, on the north side of the path, expect to find the lighter ends of each piece directed to the south east, and on the south side, to the north east; precisely what appeared to be the case, so far as could be judged from the general appearance of the masses.

The next set of facts observed, was that which relates to the course of the materials projected upwards after they had arrived at a considerable elevation. All accounts agree that the appearance of the cloud was that of a funnel or inverted cone with the apex resting on the ground. The falling rafters, scantlings, and other parts of the ruined buildings, generally indicated that they were, subsequently to the *upward* violent action, carried outward by the gradual enlargement of the current into which they had been drawn. The shingles and boards, just described, were cases in point being found far beyond the trail of the tornado as marked upon the surface. Rafters, which penetrated buildings south of the track, entered them on the north side, and in a direction inclining to the south east. Their descent, in some instances, was with great violence, contrary to what happened in the range of the upward motions; where a lad, already referred to, was deposited in safety after an aerial journey of one fourth of a mile. A window frame and brick wall were, in one instance, penetrated by a rafter, twenty feet in length, eight inches wide, and from four to six inches thick. In the passage of the storm from the city to the opposite bank of the Raritan, no indications are, of course, left to mark the peculiar action upon the waters; though we have heard it stated, but cannot say upon what authority, that the bed of the channel was laid bare, and from the nature of the forces and their violence, we cannot doubt that had it traversed a great extent of water surface, it would have assumed the character, as it certainly had the *form*, of a water spout. On encountering, however, the opposite bank, some peculiar effects were seen to have been produced. The upper edge of the bank, especially, was marked by two well defined stripes, each from ten to twenty feet wide, and one hundred, or more, feet asunder. Here, it was supposed, must have been the outer edge of the aerial trunk, or funnel through which the air rushed upwards, and as the tornado, in its onward movement, advanced against the bank, the air coming in on every side to fill up the partial vacuum would exert the greatest force at the moment when it changed its horizontal for a vertical motion. The surface of the ground beyond this point seemed, in some places, to have been raised, as if the air beneath, by its sudden rarefaction, had thrown up small portions of the soil, which was rather dry and porous; and it is, perhaps, worth consideration, whether this cause may not, in this and similar occurrences, have facilitated the overturning of trees themselves.

It was a subject of regret at the moment, that want of time, and of a suitable instrument to measure the exact course of the tornado, and the precise position of trees in the different parts of the track, prevented carrying out a plan, which suggested itself on the spot, as the most satisfactory method of arriving at precision on those points.

In conclusion it may be remarked, that the directions and intensities of the forces in this occurrence, together with the hygrometric states of the air, preceding and following the meteor, and the inverted conical form of the moving column, as confirmed by several witnesses, not less than the fall of hail, and the distribution of fragments of materials beyond the path of the ground current — seem most satisfactorily accounted for, on the supposition that a disturbance of atmospheric equilibrium, results from a deposition of moisture in the higher regions of the atmosphere giving out a great amount of latent heat; the expansion of pure air by an addition of heat, being in such cases much greater than the contraction of the atmospheric mixture by a condensation of its moisture. In this effect, is, of course, involved the well known principle that the capacity of air for heat is augmented as its volume expands, but the increase of capacity for heat being less rapid than the supply of heat from aqueous depositions, an ascending current is maintained with a force due to the difference of these two causes.[1]

The above is the testimony of Professors Henry and John-

[1] The origin of this view of the subject with which the writer had been made acquainted previously to the examination above detailed, is due to Mr. J. P. Espy.

son, proving, beyond doubt, the inward and upward motion of air in the spout. It is not a little remarkable that these gentlemen, who were the only scientific persons acquainted with my theory, are also the only ones who saw the facts so as to give any intelligible account of them.

On the 4th of July, fourteen days after the occurrence of the spout, Professor A. D. Bache (now President of the Girard College) and I visited the scene of action and commenced our examination of the phenomena, about seven miles a little south of west from Brunswick, where it appeared the spout first reached the surface of the earth.

President Bache took the direction in which the trees were lying, with a mariner's compass, and has published in the Trans. of Am. Phil. Soc., a full account of his part of the investigation, with plates, showing the direction in which the trees fell. This account is too extensive to be introduced here; I shall therefore satisfy myself with merely giving the general conclusion at which he arrives.

The very rigid manner in which it is known that President Bache pursues all his investigations, will induce the reader to place great confidence in the conclusion, even without a detail of the facts on which that conclusion is founded.

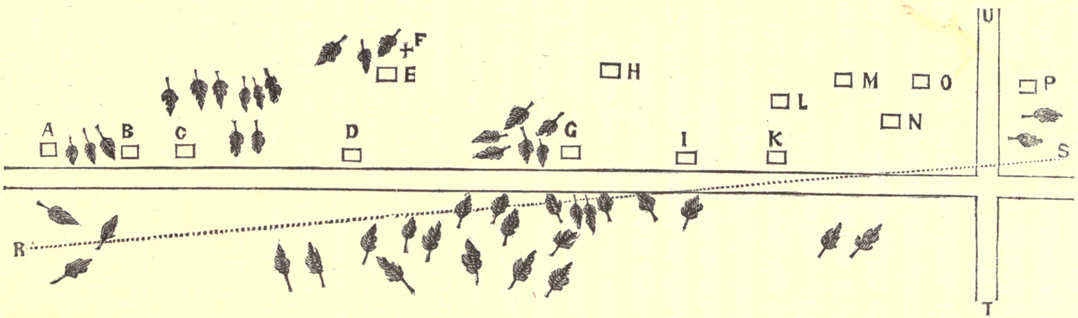
"As far as the examination of the different diagrams has shown," he says, "I think it entirely made out, that there was a rush of air in all directions at the surface of the ground towards the moving meteor; this rush of air carrying objects with it. The effects all indicate a moving column of rarefied air, without any whirling motion at or near the surface of the earth. The facts to prove that there was an upward motion, will be stated by Mr. Espy." (See Trans. Am. Phil. Soc., for 1836, pp. 415, 416, 417.)

I have a large number of facts concerning the Brunswick tornado, which I collected, both at the time I examined it with President Bache and afterwards, which I intended to give to the public; but it has been delayed so long, that I am now enabled to supply their place, nearly, by the testimony of other persons, concerning other spouts. Of course, I prefer their testimony to my own, in a case where I might be supposed to be interested.

Observations on a Hurricane which passed over Stow, in Ohio, October 20th, 1837; by ELIAS LOOMIS, Professor of Mathematics and Natural Philosophy in Western Reserve College.

[From Silliman's Journal.]

177. On the morning of October 20th, 1837, a hurricane, of destructive violence, passed over Stow, in Ohio. This town is situated about thirty miles south of Cleveland, in north latitude 41° 12′, and west longitude 81° 25′. As the hurricane occurred during the darkness of the night, we can collect little information respecting it, with the exception of the record which the wind has itself left of its progress. During the night of the 19th and morning of the 20th of October, there was a thunder shower at Stow, which extended into some of the adjoining towns. The lightning was rather vivid, the rain fell in torrents and the wind blew fresh during most of the night. About three o'clock in the morning, a whirlwind formed near the centre of Stow. It moved rapidly from west to east, over an extent of about three miles, its breadth varying from forty to sixty, and occasionally to eighty rods. For about a mile of its course, few objects were found of sufficient strength to resist the shock. The trees were almost entirely blown down or broken off; the fences were completely scattered; the houses and barns were generally unroofed, and one house torn literally into pieces. For the purpose of rendering my description more intelligible, I have drawn a plan of that part of the hurricane's track where most of the injury was done.



A, represents a house unroofed; B, a barn partly unroofed; C, a house uninjured; D, the house of Mr. Sanford, completely destroyed; E, the barn, somewhat injured; F, the spot where the cart was dropped; G, a house not much injured; H, a barn unroofed; I and K, houses unroofed; L and N, barns unroofed; M, a two story log house with its upper story taken off; O and P, houses uninjured. The horizontal road runs east and west; the perpendicular road T U, runs north to Hudson. R, S, supposed central path of tornado, moving from R to S.—This line is inserted by the Author.

The hurricane commenced a little west of the house A. Its violence rapidly increased as it advanced eastward, and throughout that whole part of the track which is represented in the diagram, a large proportion of the trees were levelled. Where no trees are represented on the diagram, there were very few, if any, to be uprooted. Eight buildings were unroofed; three others were considerably injured, and the remainder of those on the diagram escaped with a few panes of broken glass. But it was the house D, upon which the storm poured its principal violence. This was a small frame house of one story, and had been built but two years. It was situated upon a slight eminence or knoll, and was not protected at all from the fury of the wind. The house was occupied by Mr. Frederick Sanford, his wife and mother, with three children. On the evening of the 19th, the family were absent from home to attend a wedding. They returned about midnight, and Mrs. Sanford states that it was then raining moderately, the lightning was somewhat vivid, and the wind fresh. They retired to bed and were soon asleep. Mrs. S. relates that she was awakened from a sound sleep by a crash, which she presumes was occasioned by the falling chimney; almost at the same instant she felt that the house was moving; there was a tremendous roaring noise, and further than this she has no recollection. In the morning, the neighbors found the house a perfect wreck. Not a timber was left in its place. The foundation stones were not disturbed, but the entire frame of the house was lifted up, and carried in the direction of the barn E. A portion of the foundation frame was dropped almost immediately, and lay but a few feet from the foundation walls. The bricks of the chimney were, most of them, carried but a short distance, and were scattered along precisely in the direction of the barn. A considerable number of bricks, however, constituting, as is supposed, that part of the chimney which rose above the roof, were carried to a greater distance, and scattered mostly in a north east direction. The barn bore north 29° east from the house, as I determined it by a compass, and was distant from it twenty-five rods. This entire space was strewed with the small fragments of the furniture and timbers of the house. About half way between the house and barn, were found three corpses, horribly mangled, being the bodies of Mr. Sanford's two son's and his mother. Mr. Sanford was still breathing, but died in about an hour. Mrs. Sanford and her daughter were unable to move in consequence of bruises and broken bones. They are, however, still living, and will brobably recover. Animals of various kinds were lying dead among the ruins. There were pigs, geese, hens and turkeys, in considerable numbers, and several of the fowls were picked almost clean of their feathers, as if it had been done carefully by hand. Neither Mrs. Sanford nor her daughter are able to give any satisfactory account of the hurricane, for they were both of them awakened from a sound sleep by the crash of the house, and the next instant they were dashed senseless upon the ground. I have stated that the house was carried in the direction of the barn. About half of the roof and frame fell near the south west corner of the barn, and some of the timbers fell near the south east corner. Several heavy joists lay scattered forty or fifty rods beyond the barn, but all in nearly the same direction from the house. There were several very remarkable facts, showing the power of the wind, which I should not have been prepared to credit had I not observed them for myself. I visited the spot the day after the hurricane, and have observed it once since that time. An ox cart, before the storm, was standing close by, and in the rear of, Mr. Sanford's house, and was loaded with potatoes. The cart was lifted up by the wind; it soon turned a somerset, so as to empty out the potatoes upon the ground, and nearly all in a heap. The cart itself was dropped a few rods *behind the barn*, and at a distance of thirty rods from the house. If the cart moved in a straight line, it must have passed directly over the barn. Indeed, it is quite probable that such was the case; for the cart struck flat upon one wheel, which buried itself to a considerable depth in the earth. The spokes were all broken, apparently by the severity of this fall, and there is no appearance of the cart having been injured previously to the fall, with the exception of the loss of the boards which lined the body. There are no marks of the cart having been dragged along upon the ground, but on the other hand, the wheel imbedded in the earth shows that the cart fell nearly perpendicularly, and from a considerable height. It is then probable that it passed directly over the barn. There was a heavy drag, moreover, taken from nearly the same spot with the cart, and which also fell by its side beyond the barn. The roof of the barn was somewhat injured, losing some shingles and boards, and it is conjectured that the drag might have struck the roof in passing over it. I attach but little importance, however, to the question whether the cart and drag actually passed over the barn. It is at least certain, that they were transported by the wind about thirty rods, and fell from a considerable height.

A wagon, before the storm, was standing in front of the house by the road-side. The next morning one wheel was found in the road, about thirty rods east of the house; another wheel a little further north over the fence; the two remaining wheels at a still greater distance from the house, and in the direction of the barn, H. The wagon box was found half a mile distant, in a north east direction.

There is another fact, which appears to my mind still more remarkable. A very heavy cast iron plough was lying between the two houses, C and D; a massive iron chain was attached to it, and there was little wood-work about it. This plough was dragged along about four rods, and ploughed into the ground in several places. In one spot it appears to have been carried almost entirely around, removing all the turf from a space about four feet square, and throwing up the earth to the distance of six feet; the plough was broken so as to be worthless. Various light objects of clothing have been found in the neighboring towns; a sheet was found in Franklin, three miles east in a straight line; and a silk frock, with a bonnet, was found in Streetsborough, a distance of five miles, in a direction east north east.

My principal object in examining the ground has been to determine the direction of the wind's motion. This may be done tolerably well by observing the bearings of the fallen trees. Trees will usually fall very nearly in the direction of the wind which uproots them. I have therefore measured with a compass the direction of a very large number of the trees throughout that part of the track where the wind was most violent. On the north side of the road and close by the barn B, on the west side of it, one tree fell S. 7° E., another south, and another S. 9° W. Back of the house C, the trees fell S. 42° E.; S. 31° E.; and S. 12° E. A little further east, between the houses C and D, several apple trees fell in the direction S. 6° E.; S. 12° E.; S. 31° E.; S. 42° E.; S. 68° E. Those nearest the road were generally more inclined to the south than those near the borders of the track, but this rule was not without exceptions. Almost exactly north from the house D, and at the distance of about thirty rods, a tree fell S. 49° W. A little farther east, an old tree, but a stout one, fell directly towards the barn E, which bore S. 16° E.; and still farther east, being directly north from the barn, and distant about twenty rods, an oak tree, two feet in diameter, but somewhat decayed, fell S. 54° W. In this neighborhood, the whole number of trees was very small. Still further east, near the house G, but west of it, the trees fell S. 26° E.; S. 82° W.; N. 86° W.

Passing over now to the south side of the road, a few rods beyond the barn B, the trees were generally turned northward, but some eastward. Opposite the houses D, G and I, was a white-oak forest. Here the trees were not generally blown down, but broken off at an elevation from the ground of from twenty to forty feet. The stoutest white oaks of two feet diameter were snapped like a walking cane. I measured the bearings of a large number of the fallen trunks; they were N. 56° W.; N. 46° W.; N. 32° W.; N. 31° W.; N. 29° W.; N. 2° E.; and N. 14° E. Within these limits the bearings of nearly all the trees in this forest were embraced, if we except a few which lay very near the road. Here the trees were thrown down in much greater disorder; thus, directly opposite the house G, and near the road, one tree of immense size fell N. 31° W. Only two rods distant were two others of about the same dimensions, which fell S. 31° E., and then another N. 31° W. Thus here were four large trees, side by side, with their trunks as nearly parallel as they could well be laid, while the tops of two pointed northward and those of the other southward.

The preceding observations will show the direction of the fallen trees as compared with the track of the hurricane, for the latter was almost due east and west, not following absolutely a straight course, yet very nearly so. I have introduced the observations here for the sake of showing how great variety there was in the bearings of the fallen trunks, and also to show that these bearings were actually measured and not loosely estimated by the eye. A general idea of the direction of the trees will be best acquired from the diagram, in which I have attempted to represent their relative positions and bearings. It will then appear from an inspection of the diagram, that in the midst of some disorder there was a degree of uniformity. Thus upon either border of the track the trees all incline toward some point in the centre of the track. There is not an example of a tree being turned outward from the track, nor even one which lies in a direction parallel to it. I except from this remark those near the middle of the path, which were subject to a different law, as will presently be seen. Of all the trees situated near the borders of the track, the bearing which approaches nearest to parallelism with the track was in the case of an apple tree, about half way between the houses C and D. This bore S. 68° E., differing 22° from parallelism. This is a striking result, and clearly shows that the wind blew from both borders of the track towards some point in the centre of the track. This remark does not apply to one part of the track exclusively, but was a general characteristic of the hurricane. Moreover, there was one spot near the house A, where the fences on each side of the road were blown into the road.

We have then, I think, established, that there were two powerful currents of wind blowing from the opposite side of the track; that is, within a few rods of each other, and with such violence that the stoutest oaks fell before it. What then became of the air thus accumulated in the centre? It must have some escape. Was this escape in a horizontal or vertical direction? The evidence I think is sufficient to decide this question; that there was a powerful current upward from the surface of the earth near the middle of the track, is proved by the objects which were actually elevated into the air. The house D was lifted directly from its foundations. The cart which was standing near the house was raised thirty or forty feet, at the least calculation, into the air. The feather bed upon which Miss Sanford was sleeping, was found next morning lodged in a tree nearly between the house and the barn, and at an elevation of forty feet from the ground. A coat, which belonged to one of the men of the house, was lodged also in the same tree. The light articles which have been found in the neighboring towns, prove not only a horizontal current, but an ascending one sufficient to counteract the effects of gravity during several minutes.

We have now established, by a fair induction, that there was a powerful current of air from the opposite sides of the track towards some point in the centre of the track, and that here there was also a powerful current upward. What was the nature of this ascending current? Was it accompanied by gyration? This question I think we are able to answer. The furniture of the house D was scattered in very various directions. The house itself, and the more substantial part of the furniture were carried in the direction of the barn; portions of the wagon, however, lay strewed in every direction from east to north east; leaves of books were found attached to bushes by the road in an east direction; a tin pail and various light articles were found in the woods opposite the house G, and in a direction S. E. from D; and a piece of a clock was found in a north west direction from D, in the apple orchard. The plough, which was between the houses C and D, was obviously carried round nearly an entire circumference, for it left clear marks of its course on the ground. We find the same evidence of a gyral motion in the directions of the trees which fell near the middle of the track. Take the case of the four trees I have mentioned in front of the house G. They lie parallel to each other, side by side, and fell nearly at right angles to the track of the hurricane. Yet the tops of two of them incline to the north, and those of the other two to the south. Here there were two winds which blew, we cannot suppose simultaneously,[1] but successively, from opposite points of the compass at the very same spot, and the two winds must have succeeded each other at an interval not exceeding a minute, for the violence of the hurricane was past in about that time. The preceding, moreover, is a phenomenon which occurred not in one spot merely, but all along the centre of the track. Every where there is the

[1] Why not simultaneously?—Author.

same evidence of two currents in exactly opposite directions, having passed over precisely the same spot. I know of but one supposition which will explain all these phenomena, namely, that the air near the centre of the track had a whirling motion.[1] A tree then which was levelled as this whirl was approaching it, would be turned to the right for example; and another which fell as the whirl was receding, would be inclined to the left; so that we might have trees side by side, lying parallel to each other, but with their tops turned in opposite directions conformably with the observations. It appears, however, that this whirl did not extend over the breadth of the entire track, for then trees must have every where fallen, occasionally at least, parallel to the track, a fact which has been observed only near the middle of the path.

We are now, I think, in a situation to explain nearly all the phenomena which have been observed. The wind blew from the opposite sides of the track, and doubtless from every point of the compass, towards some point in the centre of the track; here the wind rose violently with a gyral motion. This vortex itself had a rapid motion from west to east, sweeping along over the middle of the hurricane's path. Trees then upon the borders of the track would every where fall towards this vortex. Those which were prostrated as the vortex was approaching, would have an inclination to the west; but those which fell as the vortex was receding, would be found inclined to the east, and we should no where find trees falling outward from the track, or even parallel to it. All this is in exact conformity with the observations. We may now, moreover, explain a fact which at first view might have seemed quite anomalous, viz. that the house D was carried in the direc-

[1] It does not appear to me, that a whirl is clearly proved by the phenomena, though it is to be expected that it must sometimes take place. The Professor does not say which way it whirled. — AUTHOR.

tion of the barn, while a tree behind the barn fell towards the house. At the surface of the earth the wind must have blown at one instant from the barn towards the house; here, however, there was an upward and gyral current; the house was raised with it, and almost immediately thrown out of its vortex by its immense centrifugal force. Lighter objects, which were carried up with it, were retained in the whirl a long time, and were finally thrown in very various and even opposite directions.

The preceding results as to the character of the wind's motion, are very similar to those which marked the New Brunswick hurricane of 1836. It is desirable that the leading features of every great hurricane should be faithfully recorded, that we may in time be enabled to decide whether the preceding characteristics pertain alike to all hurricanes; or, if otherwise, into how many classes they are to be divided.

Observations on the New Haven Tornado, by Professor Olmsted, of Yale College.

[From Silliman's Journal, for October.]

178. On the 31st of July, 1839, there occurred, on the western skirts of the city of New Haven, a tornado of the most violent class. The preceding morning had been cloudy and sultry, and, immediately previous to the tornado, a thunder storm seemed approaching from the west, attended by some appearances of high wind. I was, at the time, about a mile eastward of the track of the storm, observing the phenomenon from my chamber window. The clouds betrayed that singular agitation, which usually forebodes a hurricane, and the vane of a neighboring steeple was constantly shifting its position. A short time before the tornado commenced, the wind blew fresh from the south east, having been in this quarter during the preceding

morning; it changed suddenly to the south, and in a moment more it was west, where it continued fixed. Accompanying these changes a heavy rumbling noise was heard, not unlike the passing of a long train of railway cars, which was audible in every part of the city.

Its progress was indicated by marks of the greatest violence. Nearly every tree that came in its way through the open country, was prostrated or broken off; six houses, and a number of barns, were completely demolished; several other houses and barns were unroofed; fields of corn, then just earing, were laid close to the ground; and indeed the whole space over which the tornado had passed, presented one uniform scene of ruin and desolation.

In *extent*, this tornado appears to have been very limited. Its length did not exceed four miles, and its average breadth was only sixty rods, varying, however, a little in different places. Its *duration* at one place did not exceed half a minute, and its progressive motion may be estimated at forty miles per hour. These estimates are made by comparing the impressions and statements of various individuals who were within the limits of the storm.

The appearance of the storm as it approached, was deliberately contemplated by numerous observers who saw it coming over the plain. All describe it as a strange cloud of terrific aspect, white, like a driving snow storm, or light fog, and agitated by the most violent intestine motions. It came suddenly upon them with torrents of water — "there was a rush — a crash — and it was gone." When first seen coming over East Rock, it seemed lifted above the ridge of the mountain, but fell nearer to the earth as it descended the eastern declivity, and renewed its work of destruction when it reached the plain.

Let us now trace more particularly those facts which have a bearing upon the laws which govern this storm.

1. The first great fact that strikes us, is, that all the trees

and other objects that mark the direction of the wind which prostrated them, are, with a very few exceptions, turned inwards on both sides towards the centre of the track; while near the centre, the direction of the prostrate bodies is coincident with that of the storm.

2. On more minute inspection, we find prevailing a remarkable *law of curvature.* This is most favorably seen in corn fields, as the prostrate corn indicates the course of the wind at each spot, with great precision. The law is this. Commencing on the northern margin of the track, the stalks of corn are turned backward, that is, toward the S. E.; proceeding towards the centre of the track, their inclinations to the south become constantly less and less, turning gradually towards the course of the storm, until when we reach the centre, they lie to the N. E. exactly in the line of the storm. This curvature is in all cases more observable on the northern, than on the southern side of the track. In the latter case, the stalks of corn lie more nearly at right angles to the course of the storm, (but inclining forward); still, on reaching the centre, they turn to the north east, and become coincident with that course.

3. Numerous examples are seen where the bodies as they fell towards the centre of the track, or after they had fallen, were turned farther round towards the direction in which the tornado was moving, that is, towards the north east.

4. The ruins of buildings that were demolished, are scattered in nearly a right line towards the centre of the track; but they frequently are strewed quite across the central parts, reaching in some instances almost to the opposite margin. In this case, they are often found covered with trees, and other bodies lying in precisely the opposite direction.

5. In a few instances very limited spots are found where the prostrate bodies, as hills of corn, lie in all directions.

Examples occur where one portion of the same hill of corn is turned westward, and another portion eastward.

In a garden near H[1] are a few rows of pole beans apparently untouched by the storm, while within a few feet on either hand, the most violent effects are exhibited. Near L. a barn was demolished, and a dove-cote scattered in fragments, while a hen roost which stood feebly on blocks, was unharmed. Large trees in the immediate vicinity were torn up by the roots. A house that stood between I and L was completely torn in pieces, leaving nothing but the southern half of the ground floor. In the room of this floor, a woman was washing, and another was at work in a basement room immediately below, while her child was asleep in a cradle in a room above, at the north eastern angle of the house. They saw the tornado approaching; the woman in the basement ran up and caught her child in her arms, and immediately afterwards found herself and child in an open field a few paces north of the house, the child having been carried only a few feet from the spot where they were, while the mother was carried eighteen or twenty feet farther to the westward. The other woman, meanwhile, was swept off from the floor where she was standing and carried northward and deposited in the cellar, the floor of the northern half of the house having been borne away along with other parts of the building. None of the party were seriously injured. A bureau that was in the room where the woman was washing, was carried half a mile to the eastward, and portions of it were found sticking in the sides of a barn, having penetrated the thick wall of plank. A silk cape also was taken from this house, and carried over East Rock, to the distance of three miles. In a barn that was blown down on the east side of East Rock, a boy that was on a load of hay in the barn was transported across the street and deposited in a neighboring field unharmed.

[1] The references in this paragraph are to a diagram in Silliman's Journal, which we have not the means of copying. — *Eds. Jour. of Com.*

In other cases, however, forces seem to have acted with great violence upon the individual parts of bodies. Numerous instances occurred where hens were completely stripped of their feathers. A wagon was taken up along with the shed in which it was standing. The shed was scattered in fragments, and the wagon was carried northward a hundred feet or more, and dashed sideways against a barn, leaving a full impression of one of the wheels on the walls of the barn. Having here nearly reached the centre of the track, it took a turn to the north east and was deposited at the distance of several rods in an exceedingly mutilated state, the top having been carried off and not yet found, and the strong iron springs broken and bent in a manner that denoted an exceedingly violent action. No part of this violence is to be ascribed to the force with which it fell to the ground, for it must have fallen very gently, since the ground was scarcely broken at all. The same fact was observed in the cases of trees and other heavy bodies that were raised into the atmosphere and transported to a distance. They did not generally appear to have fallen with the ordinary force of falling bodies.

Those forces which acted upon the individual parts of a body often appear to have acted in contrary directions. The legs of the same table were found deposited at the distance of many feet from each other in different directions; and this was true also of the hinges of the same door.

We examined diligently for evidence of an explosive force acting on buildings from within, in consequence of a sudden rarefaction of the air on the outside of the building agreeably to what is reported of the New Brunswick tornado and of storms. We found but one case that favored such a supposition. This was the case of a barn where the walls were thrown out on every side, and without much apparent violence.

Destructive Tornado.

[From the Poughkeepsie Journal.]

179. On Saturday, about six o'clock, P. M., the town of Pine Plains was visited by one of the most destructive tempests this part of the country ever experienced. The day was very sultry, and towards three o'clock in the afternoon, clouds began to darken in the horizon, highly charged with the electric fluid, as was apparent from the incessant glare of lightning and continual war of thunder; the clouds mixed angrily together, which rendered the aspect sublime and beautiful, till about six o'clock, when the watery elements became more reconciled, and veered to the north of us, with little or no rain. At this juncture, our attention was arrested by the peculiar manœuvring of dark and heavy clouds a little south of west, appearing above the Stissing Mountains, about one mile distant.

As the black cloud arose, (it had the appearance and commotion of dense volumes of smoke bursting from a burning building,) light and windy clouds from all that part of the heavens, veered toward it with unspeakable confusion and velocity, apparently making it their common centre and were lost in its power. At our place of observation, in the village, a dead calm pervaded, which rendered this exhibition of Almighty power, together with its deafening war, an appalling spectacle to the beholder. After it crossed the Stissing, our view was fairer, the dark cloud with its attendants, kept close to the earth, extending upward about half way to the zenith, and, as if unable to sustain its power, was seen to burst several times, producing new rains; where these descending gusts struck, such were their fury, that nothing could resist; even the earth itself, trembled at their terrific explosions, — trees, limbs, rails, boards, hogsheads, &c., mingled with the heavens, as feathers before an ordinary storm; as it approached, our emotions were somewhat relieved, by hoping its course might be a little to our north, which proved so, from eighty to one hundred rods; nevertheless, our village materially suffered.

A barn of H. C. Myers was destroyed, and his fine orchard of fruit trees torn up root and branch. A large barn and sheds of J. Booth were felled, and his dwelling much injured. The dwelling of John Decker was blown to atoms, some of the rafters and clapboards were carried nearly one hundred rods — himself and family much injured. A large new Baptist church, almost completed, was literally piled into a heap of promiscuous rubbish; even the wall of its foundation was torn up several feet — fortunately, Mr. Northrop, master builder, and four or five of his workmen, and three or four masons, left a few minutes before. Many of the buildings were unroofed. The premises of Captain Jacob Best, a mile and half west of us, consisting of a large new barn, forty by fifty feet square, and a shed twenty by forty feet, attached to it, and other small buildings were entirely prostrated, even the foundation timbers were thrown several rods, split and broken in every possible manner; his house exhibited a melancholy wreck, unroofed, siding torn off and buried amid timbers, trees, and other promiscuous lumber; his wagons, carts and sleighs, were found wrecks, from thirty to forty rods whence they were taken, and one cart wheel was carried nearly one fourth of a mile up a hill; large apple trees were hurled thirty and forty rods, and one was carried more than half a mile by measurement; he had some cattle killed.

A Mr. Anthony Simmons, near Best's, was on the road with his team, loaded with a hogshead of sugar (twelve hundred and fifty pounds); horses, wagon and sugar were hurled over a stone wall into a perfect wreck; himself blown in an opposite direction about fifteen rods, against a gate post and stones, where he clung fast. Isaac Crandall, Samuel Gripham and Daniel Sherwood, had their barns destroyed and houses injured. Jeptah Wilbur had three large barns, cider mill, sheds, &c., torn away, so that one stick lay not upon another; his dwelling, three stories high, was stripped, except the floors; on the floor of the third story, was found a cart wheel and axle tree; his wagons and all his farming utensils, were strewed about his fields in pieces; even hams that were in his smoke house, were found in divers places, some carried more than sixty rods distant; had horses, cattle, sheep and hogs killed. Much other destruction of buildings has come to our knowledge.

This tornado took its origin near the river, as near as we can learn, and coursed easterly through Redhook, Milan, Pine Plains, North East, and became partially exhausted in Salisbury, Conn., about thirty miles distant. Its width varied from sixty to eighty rods, as appeared from its devastated path, wherein trees, limbs, tops of saplings, rails, boards, pieces of roofs, were promiscuously scattered, without the least notion where they belonged. The amount of damage is incalculable; we learn no destruction of human life, yet many persons were seriously injured. These ruins are richly worth a visit; they cannot but indicate a striking proof of Almighty Power.

The Natchez Tornado, 7th May, 1840.

NATCHEZ, MAY 30, 1840.

Matthew Henry Webster, Esq., Cor. Sec'y of the Albany Institute.

180. MY RESPECTED FRIEND; — You will herewith receive some brief observations concerning the tornado that desolated this city on the 7th instant. You may rely upon their correctness, as they were made the evening succeeding the storm. I deem it unnecessary to go into an extend-

ed detail of the circumstances connected with the tornado, as my esteemed friend, Professor Forshey, is preparing a history thereof, a copy of which you will receive in due time. With respect, H. TOOLEY.

The atmospheric temperature from the first to the sixth day of May, was higher than on the same days of the five preceding years. The range of the thermometer and barometer of the days mentioned, together with the winds and weather will be seen in the following table.

	THERMOMETER.			BAROMETER.			ATT. THER.			
Days.	6, A. M.	12, M.	6, P. M.	6, A. M.	12, M.	6, P. M.	6, A. M.	12, M.	6, P. M.	WIND'S DIRECTION AND FORCE.
1	75	79	82	29,77	29,77	29,74	78	79	82	W 3 2, N E 2
2	75	82	85	,69	,67	,58	77	81	82	S 2, S W 3 4 5
3	76	83	85	,51	,52	,52	78	83	84	S W 4 5 3
4	70	82	86	,64	,73	,70	74	83	85	S 2, N 2, N E 2
5	69	79	86	,72	,71	,63	73	79	83	E 3, W 2, N E 2
6	71	83	85	,60	,53	,45	75	81	84	S E 2, S 3 4 5
Mean,	72,6	81,3	84,8	29,65,5	29,65,5	29,60,3	75,8	81	83,3	
7	73	80		29,46	29,49		80	80		

Remarks on each day.—1. Darkly overcast all day, and very hazy. 2. Overcast, very hazy, dense cumuli, cirri of every form, windy all night. 3. Large cumuli, under scud 5, thunder, dense cumuli; the evening closes very hazy, but cloudless. 4. Morning clouds, a few cirri, the sun sets brilliantly. 5. Cirri—without a cloud—thin cirri—overcast. 6. Overcast all day, sprinkle of rain.

The seventh day was ushered in densely overcast, and very warm, with a brisk wind at S. 4, increasing at noon, and veering to the E. 5. At meridian, the southwestern sky assumed a darker and more tempestuous aspect, the gloom and turbulence increasing every moment. At 12.45

the roar of the approaching storm began to be distinctly heard, the wind blowing a gale, N. E. 6. The roar and commotion of the storm grew more loud and terrific, attended with incessant corruscations and flashes of forked lightning. As the storm approached nearer, the wind veered to the E. 7. At 1.45 the storm cloud assumed an almost pitchy darkness, curling, rushing, roaring above, below a lurid yellow dashing upward, and rapidly approaching, striking the Mississippi some six or seven miles below the city, spreading desolation upon each side, the western side being the centre of the annulus. At this time a blackness of darkness overspread the heavens, and when the annulus approached the city, the wind suddenly veered to the S. E. 8, attended with such crashing thunder as shook the solid earth. At 2 the tornado 10, burst upon the city, dashing diagonally through it, attended with such murky darkness, roaring and crashing, that the citizens saw not, heard not, knew not the wide-wasting destruction around them. The rush of the tornado over the city occupied a space of time not exceeding five minutes, the destructive blast not more than a few seconds. At this moment the barometer fell to 29.37.

The storm passed over, a comparative calm ensues. The affrighted and terror-smitten inhabitants arouse from their stupor, breathe more freely, and see around them an appalling spectacle. Every building in the city more or less injured, many utterly demolished, and very many unroofed, with their walls more or less broken and thrown down; every tree and fence prostrated, and the streets filled with scattered fragments of every kind, and nearly impassable.

The tornado, in its course, passed over Natchez under the hill, and swept it with the besom of destruction, overthrowing, crashing and demolishing almost every house, shop and building, and at one fell swoop reduced that part of the city into undistinguished ruin. Three steamboats break from their mooring; their upper works are blown off as feathers; two of them capsize and sink, and nearly all their crews and passengers perish in the storm river flood. More than sixty flat-boats, laden with up-country produce, break from their fastenings, and with their crews disappear.

In the fall of buildings, on the hill and under the hill, men, women and children are whelmed; the unhurt citizens rush to their rescue; many are dug out horribly mangled and dead; very many wounded, and bruised, and broken; the dead are buried and the living cared for. As with the heart of one man, physicians, surgeons, nurses volunteer their services and are accepted; money, provisions, and all necessaries are collected; hospitals opened, and every thing and every act that could cheer the desponding, revive the almost dying, heal the broken, are promptly administered. In the midst of the gloom and wreck the bright star of hope arises.

The news of this calamity flies upon the wings of the wind to the cities and towns, above, below; the people rush together; resolutions are passed, committees formed; money, provisions, building materials are collected, and in swift steamboats carried to the suffering city. The inland towns and villages hear of the storm, and become one with the river cities and towns, in their acts of humanity, sympathies and brotherly kindnesses are tendered and accepted, seldom equalled and never excelled, eliciting strength of character, warmth of feeling, promptness in action beyond expectation, The rubbish of fallen houses is cleared away, obstructions removed, building materials collected, mechanics work with a will; houses are rebuilt, repaired and tenanted in short time; the hum of business begins to be heard in our streets; the city revives.

The tornado in its course from the south west passed centrally through the plantation of Walton Smith, Esq., on the western side of the Mississippi, seven miles below Natchez, devastating every thing in its passage; thence up the river, the centre of the annulus being on the western side, and in its passage spread destruction on the plantations and forests for half a mile in width westwardly, and left the western bank at the bend above Natchez, crossing above and continuing its devastating course to the north east. Opposite Natchez the centre of the annulus was in the river on the western side, the river being about six-tenths of a mile wide. The wind that desolated Natchez was from the south east blowing inward to the annulus, and onward, forming a curve as it touched the annulus.

In the course of the tornado over the city in hundreds of instances proof irresistible was shown, that in the rush of the storm over a house, the external atmospheric pressure was so taken off that the atmosphere within the house suddenly expanded so as to force an outlet either by blowing off the roof, bursting open doors and windows, driving outward gable ends, or the whole or parts of walls; on the contrary, where leeward doors or windows or trap doors of the roofs were open, no such destructive effects were produced. For proof of this one meteorological fact, the following cases out of many, will suffice.

1. The garret of a brick house occupied by Thomas Armat, Esq., as an office, was closely shut up, both ends bursted outward, and such was the force of the explosive power, that some of the bricks of the windward end were thrown upon a terrace nearly on a level with the end, and at a distance of not less than twenty feet in the face of the storm.

2. A brick house on the north side of Main street, belonging to John Fletcher, had the leeward gable end thrown out, the windward end remaining uninjured.

3. The windward gable end of a large house adjoining the Commercial Bank, bursted outward against the face of the storm, the leeward end was uninjured.

4. The gable ends of a large three story brick house on Franklin street, owned by Rowan and Cartwright, were thrown outward with great force.

5. The front ends (leeward to the storm) of two brick stores owned by Eli Montgomery, were thrown outward with great force, the windward ends being uninjured.

6. Another large brick house, near the last just mentioned, owned by Watt, Burke & Co. had the leeward side nearly demolished.

7. Another brick house adjoining the last mentioned, had the windward gable end thrown outward.

8. The roof of the Theatre, a large brick building, had the entire roof blown off and thrown some ten feet forward, and the walls demolished.

9. The leeward walls of two front rooms of the Tremont House on Wall street, were thrown outward with great force, without destroying or moving the furniture therein, and where the storm could have no access.

10. The roof of the fire-proof brick office of the Probate Court, exploded to windward, that side, it is presumed, being the weakest.

11. The gable ends of a large brick store on Main and Pearl streets, were thrown outward with great force.

12. The southern side, and the northern and western gable ends of the brick Insurance buildings on Pearl and Market streets, were thrown outward with such force as to nearly demolish the building.

13. The roof of Dr. Merrill's house on State street was saved by the explosive power bursting open a large trap door in the roof, thereby making an outlet for the expanded air.

14. The leeward wall of a new wooden house owned by Rhasa Parker, on Washington street, was thrown outward by the explosive power, the windward side end remaining unbroken excepting the glass of the windows. Hundreds of facts, if need be, might be adduced to prove that when

there were no sufficient openings to let out the expanded air, the roof, or some other part of the house gave way, most generally to leeward.

The quantity of rain that fell during the passage of the tornado over the city, was only 83.100 of an inch, holding in suspension so much mud and minute particles of leaves and other vegetable matter as to be impervious to sight, and leaving a thick coating upon whatsoever it came in contact.

This brief account of the tornado will be closed by presenting to those who are skilled in the physiology of plants for further investigation, the following facts.

The effects of the storm upon the leaves and buds of plants was in a manner to sear them, abstracting or destroying so much of their vitality, that such as did not die outright, were crisped, and their growth so suspended, that it was for ten or more days before they resuscitated and began again to grow. Some very thriving grape cuttings in the garden of the writer of this paper, were killed, and the old vines stunted. Even the leaves of the succulent Morus Multicaulis appeared as if an eastern sirocco had passed over them. A luxuriant arbor vita in the writer's yard appears blighted and dying. Fruit trees and grass and weeds put on the same appearance. H. Tooley.

Storm at Natchez—Interesting Particulars—Espy's Theory.

181. We are kindly allowed to make an extract from a letter of Professor Forshey, at Natchez, to Drs. Dodge and Warder, of this city, giving some interesting facts in relation to the storm at that place, and its bearing on the theory of Mr. Espy. The reader will find among them, some things, which, if we mistake not, have never been determined before by accurate observation. The fact of the *outward explosions* of houses, desks, &c., is to us a curious phenomenon. — *Cincinnati Gazette.*

"Every thing seems to have corroborated Mr. Espy's 'Philosophy of Storms,' and every thing to militate against every other explanation of such violent atmospheric commotion. In the first place, the oppressive heat of the forenoon, and particularly just before the storm, resulting from the evolution of the heat from compression in the advance annulus of the storm. Second, the roaring sound of the wind from east to south west, gradually as the tornado was passing, keeping constantly toward the centre of the track. Third, the extreme depression of the barometer while the storm was raging, and the *explosion outward* of nearly every room and building in the city. Very often, perhaps, in one hundred cases, the gables of houses both blew out, even in the very teeth of a wind raging at several hundred feet per second! Close hatches were blown open upward, and a desk containing only one and a half cubic feet of atmosphere to each apartment, burst the locks off its three doors. Fourth, trees were *pulled* up by the roots and carried several yards, and then fell without breaking their limbs; and this happened with the largest trees. Men were picked up and carried to a distance and let down without violence or injury.

"On the two margins of the storm, the limbs and leaves of trees fell in great numbers, and the tin from the roofs of buildings was found twenty miles hence, and a piece of a steamboat window was recognised thirty miles north east from Natchez. Fifth, the position of trees was demonstration complete, in the absence of other evidence. The nearer the axis of the tornado, the nearer were their bearings parallel with that axis, and the more remote, the nearer perpendicular, while those that point to the direction from which the storm came, or cross a line perpendicular to the axis, *lie beneath* those that point in the forward direction of the same. This, you know, is the necessary position upon the hypothesis of concentric motion, while a current upward is of necessity a consequence of concentric motion.

"The exact converse of this statement is necessary on the hypothesis of gyration. The nearer the circumference, the nearer parallel with the axis of motion, and the nearer the axis, the nearer perpendicular to the same. This is untrue of all I have yet seen of this tornado, and I have seen little else since its occurrence."

Professor Forshay, in a letter to a friend, also says: — "The narrow limits of a letter, leave me room but for a few words, in regard to the special features of the tornado. It is enough to say, that had the heavens obeyed Mr. Espy's summons, and every wind rushed to the point he assigned it, and had the Omnipotent clothed him for the moment with his own dread powers, the demonstrations of his 'Philosophy of Storms' could not have been sublimer or more triumphant. I have done nothing but examine its track, and collect information since; and while I have seen thousands of corroborations of his theory, I have sought in vain for things it could not account for. The whole city of Natchez is blown towards the track I have specified; while the bearings of trees and houses falling more westwardly, are invariably superimposed by those that fell more eastwardly.

"I find, by investigating somewhat, that strange coincidences have been happening here in regard to hurricanes, and that we live in a region very much exposed to them. In May, 1823–4, two tornadoes travelled the same track precisely, with an interval of exactly a year. In 1832, on the 7th of May, the Kingston tornado fifteen miles from Natchez. It is confidently asserted, that those of 1823–4, occurred on the 7th of May. If so, the concurrence of four storms is very curious."

Water Spouts.

[From the Philadelphia Saturday Chronicle.]

182. A gentleman has handed us the following extract of a letter, which he received last summer from a friend who is in the habit of visiting the West India Islands, dated

At Sea, August 14th, 1836.

"Captain! Spouts over the lee bow!" cried the voice of a sailor down the companion ladder, yesterday, at two, P. M., while sailing along the Gulf stream, in about latitude 25° 30′.

What a singular and yet awful part of the ocean is the Gulf of Florida! The waters are here everlastingly rushing from the Caribbean sea and Gulf of Mexico, towards the more northern Atlantic; and they roll in a stream or volume of unfathomable depth, varying from eighty to a hundred miles in breadth, and being from six to ten degrees warmer than the waters on either side. Sometimes the stream travels at two knots an hour, sometimes at four, and sometimes it runs, in places, with the velocity of a mill tail. Storms, squalls, hurricanes, water spouts, lightning and thunder, give continual and terrific variety to this stupendous ocean current. Truly, it is grand, in the deep silence of a calm midnight, to pace the deck, and listen to the roaring, rushing noise of the Gulf stream, as it travels on its ceaseless course. Though this noise is partly unaccountable, yet it is mighty as the roaring of a cataract—ay, even of the Falls of Niagara. But to return to my subject.

The cry of "Spouts over the lee bow" naturally excited some little alarm amongst the passengers. The captain was on deck in a moment. I was anxious to witness the magnificient phenomena, and therefore followed him. On our arrival there, the spectacle presented by the heavens to leeward, was indeed (to me at least) of an imposing and awful character. A dark cloud, which every moment became blacker and blacker, was fast extending over the leeward sky. From the lower part of this ominous and stormy curtain, projected three jet black columns, which kept curving and swinging backwards and forwards, as if they were endowed with life.

These were the grand and mysterious hydrostatics of nature; and we were rapidly travelling into the influence of their vast machinery. At this fearfully interesting crisis, we approximated within half a mile of the nearest. So sudden had been their formation, that no time was allowed to put the ship about. We felt, or fancied we could feel, a whirling motion of the atmosphere; and more than one of us imagined that we were already in the power of the fatal tornadoes and their vortex.

"Brace round the yards! come, be quick! haul aft and load the gun, some hands," cried the captain, while he himself assisted in performing these important services.

Every second was of consequence, a minute or so might have sealed our doom. On — on — went the ship; and before she turned, we were frightfully near to the dreadful spouts. Onward and downward these gigantic hose pipes of cloud and water uncoiled. Now, they curved like a reaper's hook. Anon, they twisted like a serpent's tail! I could imagine that two of them were at least a thousand feet in length, with a body as thick as the Washington monument at Baltimore. Their contortions and convulsions were interesting and wonderful, and I found it impossible to withdraw my attention, even for a moment, from the grand phenomena; at length, the ship was put about, and we began to increase our distance from what we had regarded as a watery death. The spouts straightened out, and the lower ends of two of them approached the surface of the deep. The sea beneath rose in a hillock of waves, as if attracted or twisted into a rising *tumulus* by the cloud, or formed by the whirlwind. And now, two of the columns were perpendicular, resting upon a mount of foaming, roaring, waves—a perfect

"Hell of waters."

I should say, that from one hundred and fifty to two hundred feet above the sea, these columns were transparent as crystal, and the water might be seen swiftly travelling up them. This appearance lasted for six minutes and a half, the third spout never reaching the sea at all. Meanwhile, the entire aqueous pageant was slowly and magnificently moving towards the north; but at last, the two columns broke, one after the other, near the sea. Within a few seconds, the rain descended in such torrents that I can only compare its fury to the playing of ten thousand millions of fire engines, pointed perpendicularly down from the sky. Ten minutes after, scarcely a cloud was to be seen; and the sun blazed with a heat intense enough to "broil a beef steak upon a cannon."

And thus ends our adventure with the water spouts.

From M. Peltier, on Trombes.

183. Towards the end of August, 1838, about 3, P. M. a tornado passed near Providence, in Rhode Island. The rain was falling says Mr. Z. Allen,. in a letter to Professor Hare, with violence, when he saw a black cloud, in the midst of other brilliant and fleecy clouds, assume a terrible aspect, form itself into a black elongated cone, extending down to the surface of the earth.

Whilst he observed the progress of this cloud and of the cone which it led along in its train, and which touched the ground with its lower extremity, he saw black bodies, like a flight of black birds, with wings displayed, fall on the ground as if projected from the lower part of the clouds.

In the midst of these bodies he saw some larger ones which he recognised to be portions of boards, falling obliquely. The tornado came within a few fathoms of where he stood, and destroyed a row of buildings, whose roofs appeared to open, and in a moment to rise up in the air.

The whole house appeared to crumble, and to become but a mass of ruins in motion, which one could see through the cloud which enveloped it as a cloak of vapor.

At the moment when the obscure end of the cone passed over the crumbled building, all the debris appeared to be shot into the air, as if from an exploded mine. When the tornado arrived over the river, it produced a circle of foam, about three hundred feet in diameter; within this circle the water was agitated as that of an immense cauldron in ebullition.

When one was at a certain distance from the cloud, it appeared as a vast umbrella, of which the descending cone was the handle, losing itself in the foam of the waves of the river. The waves rose and swelled up as if by magic power, when the cone passed over the waters.

Twice he remarked a stream of light or of the electric fluid, darted across the column of vapor, which appeared to him to serve as a conductor between the water and the cloud. After this lightning, the foam of the water appeared immediately diminished for a moment, as if the agitation of the surface of the water was calmed for a moment by the electric discharge.

The motion of the tornado was almost in a right line in the direction of the wind [from west to east] and its velocity was about eight or ten miles an hour. Although he was at the exterior limit of the circle of the tornado, he felt no extraordinary gust, he only perceived the same current which existed, before the arrival of the meteor.

He remarked also that the temperature did not appear more elevated in the air neigboring to the borders of the whirlwind, though that would have been indispensable, to produce the rarefaction necessary to cause an ascendant current. The tornado, after having traversed the river, continued its route, carried off every thing which it met, and he lost sight of it, in the midst of the vapors, and clouds of every kind which obscured the sky.

Mr. Tillinghast, who was on a hill, says the cone was sometimes so prolonged that it touched the earth, at other times it passed over spaces without touching them. At each contact with the soil, or with terrestrial bodies, it suddenly elevated a cloud of dust, and fragments of broken bodies, which were lost in the cone.

A pond was made almost dry, trees were torn up by the roots and despoiled of their leaves and their branches, the houses were unroofed, and the roofs carried off or broken, the farms lost their grain, their fruits, and their fowls. The human species were not free from this disaster. Two women were carried off from their carriage, and transported over a wall into a neighboring field. In the same village a cellar door and its frame were lifted off, and deposited on one of the sides of their former place, though this side was next the wind.

This effect appeared the more extraordinary as the wind coming against this inclined plane, ought to have pressed this door against its foundations. The author of this account, attributing this effect to the dilatation of the wind, adds, in consequence of this dilatation of the air, which took off this door and the frame, a part of a roof on the side from the wind burst open, while that on the windward side was not damaged. (p. 363.)

The author will add here that Mrs. Tillinghast, of Providence, told him that she watched the tornado after it passed on to the east, and saw two showers of rain falling from the cloud to which the trunk was attached, one on the south and the other on the north of the trunk, and she particularly noticed that these showers did not fall perpendicularly, but both sloped inwards towards the spout below.

184. On the 13th September 1835, a tornado ravaged the commune of Caux. Its march was from the S. W. to N. E. tearing down trees and overturning houses. It carried off all the water of a pond and all the fishes which it contained, and threw them down a league and a half from there, to the great astonishment of the persons who witnessed this ichthyological rain. (*Peltier sur Trombes*, p. 42.)

185. In a tornado which ravaged the environs of Carcasonne, on the 3d of November, 1780, as it passed over a chateau, it furrowed and raised up the pavements of some of the apartments, and in another chamber this effect was produced only in the centre, and in the same chamber piles of china ware placed around were undisturbed. Large stones were transported to the roof of the chateau, and a large tree was left on the roof of a peasant's house. The tornado was preceded and followed by no rain at Leüc, but at the place where it commenced, and also at the village of Villarbe, there fell a great flood of rain. (p. 48.)

186. On Good Friday, 1666, there fell a great quantity of little (merlans) sea fish, of the size of the little finger, in a field at Cranstead, near Wrotham, in the county of Kent. This place is distant from the sea, and from any large piece of water. At this moment there was a great tempest, accompanied by thunder and rain. (p. 75.)

187. Some of these meteors have been known to encounter ships in their march, and then the column of water which constituted them, and which had just risen from the sea, instead of continuing to rise, flowed down on the ship; such is the fact related by Capt. Melling, of Boston; and in this case it fell in such abundance that it was with difficulty the captain preserved himself from being washed overboard. He states that the water which entered his nose and mouth was entirely sweet and fresh; and all sailors

who have ever tasted the water in similar cases affirm that it is fresh. (p. 76.)

188. White squalls (*les grains blancs*) are very rare, but they are sometimes met with between the tropics, especially near elevated lands; they are generally violent, and of short duration. They often take place when the sky is clear, and without any atmospheric circumstance giving notice of their approach. The only thing which indicates their proximity, is the boiling of the sea, which is very much agitated by the violence of the winds. Many of these squalls, which commence either by a little cloud or even without any visible cloud, are very soon accompanied by violent rains and thick clouds. (p. 101.)

189. The reader will be able to form some idea of the electric theory of M. Peltier from the following very brief extract, p. 145.

When the cone is formed entirely of the vapors of the cloud, and when its specific gravity does not oppose itself to its descent to the ground, or near the ground, the descending cone will have a great power of attraction, and it is not till after they have exchanged their opposite electricities, that the bodies attracted will be repulsed. But if, on the contrary, the descending cone is maintained at a great height, if it is vapors or dust raised from the earth, which form the lower part, and go to neutralize the electricity of the clouds at that distance, the terrestrial objects placed near the ascending cone, being electrized in the same manner as it, will be repelled and projected from the centre to the circumference, with a violence proportioned to the extent and force of the electric tension, which the ascending cone possesses. Thus two sorts of tensions may exist in the lower portion of spouts, according to their origin, and may thus produce two contrary effects on terrestrial objects.

If this portion is a dependence of the cloud, the terrestrial bodies will be attracted; if it is formed of vapors or of objects taken up from the surface of the earth, it will repel all the neighboring objects, since they will all have the electricity developed by the same influence. It may happen, and it often does happen, that during the continuance of a spout, these two conditions present themselves successively according to the state of the soil, or the specific levity of the clouds which lend themselves or oppose themselves to descent.

It is sufficient to read some accounts of these spouts, to be assured that the force is sometimes attractive and sometimes repulsive; and in the first case the objects are thrown towards a centre, and in the second, in the opposite direction. The forest of water (*bosquets*) at the foot of the spouts, is the product of attraction at first, then of repulsion, when the drops of water raised up have changed their electricity.

The immediate cause of the lowering of one of the clouds, may vary from one spout to another, though it may be the product of the same power. In the meteor of storms, a cloud but little elevated above the ground, and very highly charged with electricity, may be attracted by the contrary electricity, which is accumulated on a portion of the soil underneath (*en regard*) and so much the more as the ground is more elevated, humid and good conductor; the electric tension of the soil reacts on that of the cloud, neutralizes the reaction, which the lower portion produced on the rest of the electricity of the cloud, as the lower plate of a condenser neutralizes the reaction of the stratum of electricity of the upper plate. This reaction of the lower electric stratum of the cloud being neutralized, a new communication is made to the inferior surface, a greater mass of statical electicity is accumulated there, and so in succession; during which the exterior electric charge is augmented, the cloud, being a movable body, is attracted and approaches the earth, a quantity depending on its specific gravity, and on the square of the accumulated charge. Having arrived at a certain distance, the attraction of the two electricities preponderates over the resistance of the air; a discharge takes place, the cloud rises, until a new communication of electricity takes place, producing an equal state and an equal result. The electric change, as we see, is made between the atmospheres which surround the bodies, it is the positive and exterior quantities of the cloud, which are neutralized, with an equal portion of negative and exterior electricity of the soil. But the sphere of electricity, which surrounds, is not formed by all the electricity which it contains, as that of a globe of metal, which does not hold any portion in its interior; it is, on the contrary, often only a very small portion of the whole, a portion which is dependent on the interior reactions and conductibility. A cloud being composed of a multitude of distinct bodies, of particules of vapor called vesicular, each of these vesicules has its electric sphere, which is inherent in it; according to their proximity, or, what amounts to the same thing, according to the density of the cloud, the reaction of these spheres, the one on the other, repels to the periphery a part of their electricity until the exterior reaction is equal to the interior reactions. This exterior quantity will be so much the smaller as the insulation of the particles of vapor is more perfect.

If the insulation is great, if the radiation towards the periphery is weak, there will result a great tension, and consequently a great attraction, which will bring the clouds near the ground, without producing a discharge sufficient to render the specific levity of the cloud predominant. It is to this weak exterior reaction, that we must refer the division of one spout into several.

When the periphery possesses a sufficient quantity of free electricity, which acts by repulsion, on all the electricities, of the same nature of the vesicules, the whole of the vapors is maintained, in one body; if this force is insufficient, the interior repulsions obtain the preponderance, and the spout is divided. We shall frequently find these re-unions, and these divisions, when we treat of clouds in a special manner.

Thus when each of the vesicules of vapor, preserves a very great tension, and their insulation the one from the other prevents that of the cloud from being considerable, the whole of the cloud is attracted and not merely the electric charge of the surface; the specific gravity of the cloud is overcome by this attraction, the cloud lowers and approaches the earth. While this movement is effected, the attraction increases in a proportion greater than the proximity, as it increases inversely as the square of the distance; the cloud continues then to descend, and it would descend with great velocity, if each vesicular particle could receive rapidly, the electric quantities necessary to replace those which escape by accelerated radiation, and which become so much more indispensable as the density of the air augments.

The feeble conductibility of the clouds does not, without slowness, difficulty, and inequality, permit the electricity of the superior clouds to arrive into the parts nearer the earth. The electric diffusion, cannot be returned, but very unequally, in bodies so varied, in their forms, and in the relations (*rapports*) of their constituent parts.

The disposition and constitution of the clouds, do not permit but very rarely the descent of a portion of cloud down to the ground, principally in our country, for as soon as the density of the cloud permits a tolerable conduction, the electric tension transfers itself to the exterior, the discharges take place in mass, and the cloud rises. It is then a storm and not a spout.

We see then that a union of circumstances very favorable, is necessary, that the particles of vapor may have an insulation necessary to produce the lowering of the cloud down to the earth, without its making a discharge of the electricity, whose attraction counterbalances the levity of the cloud. It is necessary, also, that a rapid evaporation should produce, in a little time, a considerable quantity of electricity, and that there should be a very great calm in the atmosphere to preserve it.

These circumstances not being common beyond the tropical heats, the spouts would be infinitely rare in our regions, if a secondary cause did not come to determine the formation. This secondary cause is the presence of a cloud or a group of clouds more elevated, possessing the same electricity as the inferior group.

The action of the superior clouds, repelling the inferior ones facilitates their descent, it will be sufficient that these latter should have the constitution proper to preserve a strong electric tension, and the conductibility there be very feeble, that they may be drawn down to the very ground, and thus form, the conducting and intermittent column, which is called water spout.

In fine, observations carefully made teach us that the extremity of the cone extends or shortens itself according to localities, that it balances and undulates, leaps from one place to another, from one cluster of trees to another, and abandons moist places, not without manifest resistance; that in the centre is seen a canal, transparent, according to some, luminous, according to others; that in all there is an intestine movement, here and there, sometimes direct, sometimes giratory, varying without ceasing, and from one portion to another, as we see in electrified smoke. Every observer has expressed the impression which he experienced, and in reality, when the approximation of the vapors to the extremity of the cone is such, that there results a real liquidity, this liquid and transparent medium remains suspended between the rest of the cloud and the sea; at other times, on the contrary, the distance of the particles of vapor is so great, that the electric communication, cannot be made but by little discharges, of which the multiplicity of sparks produces a hissing noise and the phosphorescent light, which certain observers have seen. The phenomena of statical and dynamical electricity, explain all the parts of the meteor, whatever may be the variety of its forms, and of its effects, without having recourse to any hypothetic creation; it is sufficient to keep in mind the electric tension, its reproduction, the conductibility of localities, and their saturation. Since we now know all the atmospheric circumstances which produce electric forces, and how to distinguish the primitive causes from the secondary, we will give an account of the spout which devastated the Communes of Fontenay and Châtenay, [near Paris] on the 18th of June. 1839, and shew that every where the electric power was the primitive cause of the meteor, and of the disasters which it produced, disasters which were augmented by secondary causes, by the impetuous winds which accompanied the storm-clouds, and by the suddenness of the blasts. p. 145 — 150.

190. On the 18th June, 1839, in the morning, thick vapors had risen in the horizon, and formed a long band, which extended, from the south to the north east of the hill of Châtenay. The atmosphere was warm and dull. A little before ten o'clock some claps of thunder were heard at a distance; these claps became louder and more frequent; and towards eleven o'clock the storm roared on all sides. The heaven was streaked with long and brilliant lightnings, and the rolling of the thunder was continual. This first storm having formed to the south of Châtenay, followed the ordinary march of storms, and took the direction of the valley which separates this village, from east to west, from the hills of d'Ecouen. The clouds of which it

was formed, extended up to the hill of Châtenay, and appeared then stationary, and about to resolve themselves in rain to the west. But at midday a second storm appeared, whose clouds, less elevated than those of the former, moved rapidly and advanced towards the hill. These clouds having arrived at the extremity of the great plain of Fontenay, in presence of those which were then over Châtenay, relaxed in their march, and a sort of combat seemed to take place between the first and second storm, and one could not foresee which would carry the day, nor what direction the last arrived clouds would take. Many inhabitants observed this combat with a curiosity mingled with anxiety, not knowing to what to attribute so singular a perturbation. We mention, among others, Mr. Dutour, an intelligent man, and admirably placed to make this observation, Mr. Robinet, the elder, and Madam Bulot, of Fontenay. A great agitation then manifested itself, in the intermediate parts, and the thunder rolled violently, when all at once the clouds of the second storm lowered themselves towards the earth, and put themselves in communication with it. At this instant the thunder appeared to cease, and there arose a frightful whirlwind of dust and of light bodies, with an extraordinary and confused rolling. A shepherd, named Olivier, was in the avenue of Pontoise, very near the place where the spout was formed. The storm, said he, descended and approached the earth; some of the clouds were detached from others, and formed a whirlwind. Among the clouds there was a little one which did not follow the march of the others; it came directly towards me; then all at once it returned on the other side, rose up and disappeared. The inferior cloud of the storm was very low, almost on my head, and so thick that I could not see at some steps; at the moment of its descent I heard a loud clap of thunder, and this was the last, for after this there was nothing but a rolling and continual trembling.

The point of ground with which the descending cloud put itself in communication, made a part of a field to the west of the avenue of junipers, very near a grove of Swiss poplars. The trees which bordered this avenue were consequently to the east of the spout, which advanced from the south to the north. On the west side of these trees, that is to say, on the side next the passage of the spout, all the leaves were dried and scorched on their borders, while the leaves of the opposite side towards the east, had preserved their freshness and their verdure. All these trees were inclined to the west, a little north; instead of being straight, they were bent towards the place of the passage of the spout.

Thus those trees affected by the influence of the spout, and not directly in it, had all the leaves withered, like the leaves which have been used in powerful electrical discharges; but preserved all their leaves untouched on the side where there could not be any radiations. We know not, says Mr. Peltier, how the most fertile imagination could refer this fact to the influence of a whirlwind, and deny its connexion with electric radiation, and it is impossible, not to recognise, in the little cloud approaching the shepherd, and then flying, an effect of statical electricity, accompanied by radiation.

Mr. Dutour, who made his observations from the terrace on the top of his house, saw the formation of the spout at a distance, and assigned to it the same part of the field; but he saw what the shepherd could not see, as he was blinded by the cloud of dust, in the midst of which he was — the extremity of the cone, according to his expression, *a red cap of fire*, which appeared to be eight metres from the earth.

The spout increased very soon in intensity, deviated towards the north east, and came near to the Croix du Frèche.

It was animated, says Mr. Lalanne, engineer of bridges and roads, with a very manifest oscillatory motion both vertical and horizontal, like a pendulum which should be successively approximated to the clouds and removed from them, and at the same time balancing itself around the point of suspension.

Between its place of departure and the Croix du Frèche, there was a great space of the avenue without trees.

After the junction of St. Dennis, two hundred and fifty metres further on, there were fruit trees on the borders of its path ; these trees had on the west north west like the first, all their leaves dried and scorched, whilst the leaves on the east south east were preserved fresh. These trees were not merely inclined, but entirely prostrated, and lying on the ground, turned towards the west north west. A cherry tree was torn up and divided into two portions, the portion which was separated from the (culée) was divided into little splinters like thin laths, such as one finds in the trees which have been struck with thunder, and which have served as conductor to a powerful discharge.

Arrived at the Croix du Frèche, the descendant cloud had great dimensions ; it was then a terrestrial spout well formed, which, according to the account of several inhabitants of Fontenay, had the form of an inverted cone, having its base in the upper clouds, and its apex, about seven metres from the earth. The vapors which composed it had a grey tint, and rolled one on the other with a great impetuosity, letting some points of their pale light be seen, and causing a confused rolling to be heard. The spout then began to deviate from its first direction, and went to the north east, towards a little row of trees along a brook without water, but somewhat moist. It overturned them all in the direction of its march, and it split them into slender strips, in the slenderest part of their trunks. It passed at the south west extremity of the village of Fontenay, reached the farms of

MM. Lecerf and Destois, destroyed and carried off their roofs, overturned the walls of their enclosures in the direction of its march, and devastated their enclosures. Continuing then its course along the moist ravine, bordered with trees, it advanced towards the hill of Châtenay, which it began to ascend as far as the enclosure Plant Thibault, which it destroyed entirely. The trees affected by the meteor, presented the same peculiarities, as those mentioned before; the side struck was dried, while the opposite side preserved the sap, besides the parts of the trunks broken, were reduced to thin strips, and some had the appearance of a broom.

M. Dutour, who had followed, with uninterrupted attention, the progress of the phenomenon from the top of his house, says, that at this moment there was a combat between a grey ash colored cloud, belonging to the first storm, which, up to that time, had remained stationary, and the anterior cloud of the second storm, now transformed into a spout. The march of the spout was thus arrested, for some minutes over Plant Thibault, but it succeeded in displacing the grey cloud, and repelling it, then it was able to reach the summit of Châtenay. Little greyish clouds rose and descended in protuberances along the inverted cone. The spout itself seemed composed of nothing but a great number of little louds, *qui jouaient tous pour leur compte*, in keeping themselves shut up in the cone.

The whole made a noise like a large steam engine in action. . . . . From her locality, Madam Bulot had seen the parasite clouds, which she compared to funnels turning on themselves; she saw also flames fall on the trees or near them. Madam Ferrière and her domestic, saw the fiery extremity of the cone, which they compared to the flame, which comes out of a blacksmith's forge. The spout seemed to wag its tail, as her husband said, which accords with the oscillations of M. Lalanne.

Thus far, all the trees, and walls overturned directly by the spout, were in the direction of its march with but little deviation.

From Plant Thibault, it would have directed itself infallibly towards the wood of Châtenay, to the west of the castle, if the first storm had not protected it. The spout deviated then to the N. N. E. and in climbing the hill, it destroyed some poplars which it found in its course.

Two thirds of these trees were thrown down in the direction of its path, the other third in a different direction.

Having arrived on the summit of the hill, it shook the houses situated in the street of Mareil; it took off the roofs, broke the windows, scorched the curtains. Miss Beaucerf, who was shut up in her chamber, saw some sparks fall by her chimney, though she had no fire, nor any of her neighbors. Some linen placed on the table, was carried off through the chimney, and transported to a distance. M. Peltier, adds, that this effect could not have been produced by a vacuum, and that nothing but an electric attraction could have produced it, and that all these places preserved for a long time the smell of burnt sulphur.

In following the march of the meteor, and the line of the trees thrown down, it appeared evident that the destruction of the houses of this street was not caused by the direct passage of the spout, but by lateral influence, for the trees of the orchard of M. Herelle indicated that the column passed between this orchard and the road of Fontenay to Fosses, and not between this orchard, and the street of Mareil. All the fruit trees of this orchard were thrown down towards the N. N. W., whilst those of the road of Fontenay to Fosses, which was parallel to it at about 25 metres, were thrown towards the N. N. E. From this place, the spout deviated again a little to the east, entered the park of the castle, and devastated it in the most disastrous manner. All the trees of the high forest were torn down, three quarters of them had their trunks dried and split into small splinters, or in the form of a broom. The centre of the park had its trees overturned, in the most singular manner, and an apple tree was carried 200 metres and placed on a pile of oaks and elms.

But this confusion only existed in the centre; all the trees in the periphery had been thrown down with their tops towards the centre of the park, as M. Lalanne has shown in the plan which he made. The spout carried away almost all the roof of the habitation, and overturned the walls of the enclosure. What was remarkable in this last effect is, that one of the walls, between the farm and the castle, was overturned in five portions almost equal, of seven or eight metres each. The first, the third and the fifth, fell towards the north east, and the second and the fourth, towards the south west. The slaters of M. Herelle, proprietor of the castle, declare that several rows of slate had lost their nails, without the slates being moved from their places; they seemed as if they had been replaced by the hand of man.

This fact, almost incredible at first, says M. Peltier, ceases to be so when we compare it with others already known. The nails of sofas and arm-chairs taken off, bricks and slabs raised up and left in place, a frame taken away without doing any damage to the looking glass. These facts accord perfectly with the attractive force of statical electricity, and the preference of its choices, but become a complete absurdity with a whirlwind for a cause.

The farm belonging to the castle suffered grievously from the passage of the spout; three quarters of the buildings lost their roofs; the walls and the doors against which the spout projected itself, were covered with a layer of earth from the fields.

After the immense energy which the spout expended from its formation, it seemed now to arrive at its extreme limits; it took up nothing more, but it let go the light earth which it had taken up before, and which it had scattered in its borders. A field of corn on the north west of the park, felt the influence of the spout; all the stalks nearest to the passage of the meteor, had their ears scorched on the side next the spout on the south east, while the side opposite was left untouched and green. The hill on which the castle is built, terminates abruptly towards the north east, and the ravine below is filled with the waters of a pond. Some willows were in the middle, and consequently served as so many points of attraction. The spout did not prolong itself immediately, to establish the communication which had just been broken; there was at first a discharge at a distance, producing a large flame, which appeared to fall from the cone into the pond. This globe of fire was seen by Madam Louvet and her daughter, who found herself near the pond at this time. The young girl was hurried along about ten metres without being able to resist the force; at last she stopped herself by clinging to the trunk of a tree on the outside of its path.

The electric discharge produced an effect which is well known, and which we have often produced in our microscopic experiments; that is, to kill the animals contained in the liquid by electric discharges at a distance. This is what happened at Châtenay. A great number of fishes were killed by the discharge which took place at the moment when the communication was established between the spout and the pond. The half of the trees which bordered it were more or less broken, dried and split into splinters.

After having remained a moment on the pond, the spout advanced along a ditch full of water and bordered with willows; it had lost its violence and its extent; it travelled slowly, and traversed more slowly still a field situated beyond the pond. In advancing across the field, the spout became visibly more slender and more transparent; in fine, at about one thousand metres from Châtenay, near a clump of trees, at an avenue called the Fosse, it was reduced to the size of a stove pipe. It was here that it terminated, having first divided itself in two. The upper part appeared itself divided into ribbons of a brown and white color, and it dissipated by degrees, in rising up like a light smoke, the lower part appeared darker, and settled down on the ground.

An excavation was found in this place, which had not been remarked before. All being terminated, the heaven recovered its serenity; and no one could doubt of the horrible tempest which had just passed over the commune, without the debris of all kinds which covered the earth.

Though there were only four or five inhabitants at Fontenay and Châtenay, who saw the globes of fire or flames interpose themselves between the ground and the spout, or between the parasite clouds, it was not the same with those who saw the meteor at a greater distance, and who were entirely beyond the influence of the clouds forming and accompanying the spout. M. Dardelle, when he perceived a cloud of fire burst over Châtenay, was so persuaded that it must be burnt, that he came express the next day, in the morning, to see and know all the evils which must have resulted from such a conflagration. All these united facts leave no doubt, says M. Peltier, as to the first cause of this phenomenon; every where we find electric phenomena; every where we see statical results of attractions and repulsions, and continued discharges between the little bodies. The passage of M. Dutour, cited above, is remarkable, in which he represents the cone of the spout as formed by a number of small clouds, sporting with each other, as our artificial clouds, serving for conductors of electricity. The raising and tearing away of heavy bodies are also the effects of this powerful tension, which the clouds alone can acquire, and which none of our experiments can at all equal. Nothing can give us an idea of the enormous quantity of electricity which the clouds can acquire, if we do not attend each year to those violent storms which, for whole hours, are like enflamed volcanoes darting from all parts long furrows of fire.

We have not, says M. Peltier, mentioned the calculations of M. Lalanne, on the force sufficient to overturn the walls, because this distinguished engineer set out with the supposition that the wind was the disturbing force; but, according to my researches and my experiments, this force plays but a secondary role: it is the electric attraction which is the first cause; it is that which we have seen besides tear up the floors of chambers, penetrate and furrow the earth, transport walls and debris of all kinds against the course of the spout and the wind. The wind could not give an account of the wall that was overturned in five parts, of which the first, the third, and the fifth, were thrown towards the north east, the second and the fourth towards the south west; whilst one of the particulars, often remarked in spouts, and in particular, in that of Châtenay, is an oscillatory movement of the extremity of the cone, which projects from right to left the objects which it meets, an effect of which we indicated the cause above. In fine, says M. Peltier, I rely on the authority of M. Becquerel. This savant visited the places with me; he followed the march of the meteor; he saw the havoc which it made; he examined the witnesses concerning it, and he saw, like me, but one interpretation possible, that of electricity for the cause. (p. 151.)

Not comprehending the connection between the storm cloud and the violent gust of wind, they have attributed to the latter all the effects, of which the cause remained unknown, notwithstanding the impossibility of finding an origin beyond the narrow limits of the perturbation, round which calm and tranquillity reign. I never have been able to comprehend how they have misunderstood the power of attraction and repulsion of the electricity of these thick and isolated clouds which swim in a pure and serene sky. Both before and after their arrival, the atmosphere is calm, but at their approach, violent gusts arise, coming from all parts; the rain itself often terminates the phenomena, and when the cloud passes away to a distance, the serenity of the heaven returns. From this necessity of referring to the visible part of the meteor every thing which had an unknown cause, they have attributed to the agitation of the air a power altogether miraculous. The tearing up of floors and pavements, the lifting of earth and foundations, cannot be explained by blasts of wind, however violent they may be. A whirlwind would raise up the water and not distil it, to form immediately ascending clouds, as we see around the water spout; never could it evaporate the water beyond its point of saturation: consequently, never would the vapor formed become immediately visible. The effect is local and of little extent in the midst of a calm in surrounding regions. The dilatations and contractions which they assign for cause in the atmosphere, never could produce those sudden blasts: the electric discharges alone are able to produce such effects; they alone can pass from repose to action, from attraction to repulsion in a moment; they alone can evaporate suddenly a considerable quantity of water, beyond the saturation of the ambient air, and cool the atmosphere and the clouds by evaporating again the opaque vapors; they alone can transport trees and houses contrary to the wind, and produce all these effects, when hardly a breath of air is felt; these alone could wilt the leaves, crisp them, and redden them on the sides next the spout, and leave them untouched on the opposite side. (p. 142.)

191. Mr. Tilloch has inserted an account of a spout, which appeared on the 17th of June, 1817, at Kentish-Town, marching from east to west, and which was seen by the Editor of the Monthly Magazine.

This spout was formed of udders of cloud grouped together in form of an inverted cone. It descended two thirds of the space, and the portions of the cloud of which it was composed were in the violent agitation of a smoke which ascends a chimney of a fire which has just been filled with a combustible. The spout did not preserve the length which it had attained; it retired towards the cloud, and took the form of a large short cone, terminated by an elongated filament, varying in length and thickness, which lasted six minutes. The meteor continued for half an hour, when a considerable shower fell from the cloud to which it was attached.

Among the effects which it produced, we remarked a loaded wagon which it took up and carried twenty yards.

The witnesses which saw it very near, use words which do not indicate that the cone had a gyratory motion, which it would have had if it had been produced by a whirlwind, as Mr. Tilloch thinks; *they describe it as a vast mass of smoke*, working about in great agitation. This cone fell almost perpendicularly, a little inclined towards the north, according to some, and a little towards the south, according to others; but all say it rose without rain, and that under its extremity, all light bodies followed it. The witnesses also said that in its lowering, it appeared to hesitate, and it commenced at first by an udder, then descended a little: all the portions were interwoven and united together till the moment when it began to shorten itself, and then it drew itself up into the cloud.

Mr. Tilloch draws these theoretic conclusions from this single observation.

1. A spout is a collection of clouds of the same nature as the cloud from which it descends.

2. Its descent is a mechanical effect of a whirlwind, which creates a void in the centre, or a great rarefaction between the clouds and the earth: the clouds descend then by their

own weight, or by the pressure of the neighboring clouds, or of the air.

3. The circular movements of the descending mass, and the whirlwind felt at the earth, and the appearance of the clouds at its origin, during its increase and decrease, all demonstrate that it is a whirlwind which is the mechanical cause of it.

4. The same whirlwind which provokes the descent of the cloud, provokes the ascent of bodies placed on the surface of the soil.

5. If the whirlwind takes place above the water, the ascending column is formed of vapors, of foam, or of water.

6. When the phenomenon terminates, the light bodies fall and the cloud ascends.

7. When the lower light bodies are of water, it is probable that the ascending vapor unites itself to the spout, condenses the clouds, which form it, at this point, and the water falls as if through a syphon.

8. If the descending cloud is electrical, it may send a discharge on the conductor which is presented to it; and still more, it pours down on its route that which it had taken up before, at first, and it is this which produces these strange phenomena of a rain of fishes and frogs, &c., &c.

9. It appears certain that the action of the air on the clouds, pressing on the mouth of the whirlwind as on a funnel, augments the condensation to such a degree that the fall of water belongs to the prodigy. (p. 341.)

How far electricity is concerned as a *cause* in the production of some of the phenomena detailed above, I am not prepared to say. As an *effect* of the sudden condensation of large quantities of aqueous vapor in the air, it is pretty well understood. [See Pouillet's Elements de Physique, Art. 270.] But as all effects in nature become themselves causes, and as the utility of atmospheric electricity has not yet been discovered, we must be careful not to attribute on the one hand, to the action of electricity effects which are plainly accounted for by the dynamical agency necessarily resulting from the diminished weight of a suddenly formed cloud, nor on the other to deny that any effects whatever are produced by the immense quantities of electricity developed by the condensation of the vapor.

If it shall hereafter be proved by well authenticated observation that the barometer sometimes falls more than three inches in the centre of one of these spouts, then it will become necessary to look out for some other cause besides the one I have assigned, to account for part of the effect. Even then the cause which I have assigned will remain a *vera causa*, but not the sole cause.

As to the drying up of the leaves of the trees on the passage of a spout, it may be electricity for aught I know, or it may be the violent force of the wind upon them. So far as I have been able to learn, the leaves and grass remain perfectly green immediately after the passage of a spout, but on the next day they wither away.

Many persons told me that the limbs of the trees which fell on Staten Island along with a shower of hail and shingles on the evening of the 19th June, 1835, had the leaves perfectly fresh and green. And President Bache and I observed that many of the leaves in the Brunswick spout were torn and pierced with numerous holes by the sand and gravel stones and particles of earth, carried along with great velocity by the wind; this was quite evident, as we found much sand and pebbles imbedded in the bark of the trees. I would not be understood to say that electricity had nothing to do with this phenomenon.

Professor Olmsted says, (178) "the forces which acted upon the individual parts of a body, often appear to have acted in a contrary direction. The legs of the same table were found deposited at the distance of many feet from each other in different directions; and this was true also of the hinges of the same door."

These facts are easily accounted for without supposing that the forces acted in a contrary direction. Nothing is more common than for light bodies, and even heavy ones to be thrown towards the centre of the approaching meteor with such force as to break to pieces on striking the ground, and then parts of the broken body will remain, and parts will be carried forward by the rear of the spout.

This is the case with many trees, which break in their fall; the trunk remains where it fell, while the top is carried sometimes to a great distance in the direction in which the spout moves, and sometimes remaining attached, will only be twisted round.

In this very spout several instances of that kind occurred, and also others of a similar character. For example, in the house which the professor mentions as being removed from its foundations, leaving one woman in a cellar and carrying another away some distance, was a box of carpenter's tools; and after the spout had passed on, a chisel which was in the box at the approach of the spout, was found sticking fast in the western wall of the house.

This explanation does not apply to stripping off the feathers from chickens, the removing of frames from looking glasses without disturbing the glass, nor the drawing of nails from the roofs of houses without disturbing the tiles. The steam power generated or rather let loose in this meteor is totally inadequate to produce these effects. All the evidence which is known for the latter fact perhaps still leaves it doubtful; but there is no doubt as to the stripping of the chickens. Many proofs of it have come to my knowledge beside those detailed in this book. To satisfy myself whether a sudden rarefaction of air on the outside of a chicken would cause an explosion of the feathers from its body, one was placed in the receiver of an air pump, and a very rapid exhaustion effected without producing any such effect.

Nor do I know any experiments going to shew how electricity could produce the phenomenon.

M. Babinet told me that he knew instances in which the hair on the *mons veneris* and in the *arm pits* was entirely removed from persons killed by lightning, while that on the head was not disturbed.

In the case of the chickens, however, they were not killed outright, but were seen walking about in all their naked simplicity after the spout had passed on. Nor do I recollect to have heard of one well authenticated case of death by electricity, in this meteor, of persons in houses exploded in such a manner as to have their walls found lying on all sides of their foundations. I have heard it also confidently asserted that many persons in the Natchez tornado were stripped entirely naked, who had not experienced any very severe bodily injury; but I am not able to vouch for the truth of the story. If it is so, it is like the stripping of the chickens; a fact not yet fully explained.

But if these particular effects should be found to depend on electricity, as it is highly probable they do, it will not follow that all the other phenomena of tornadoes depend on electricity also.

Many of them manifestly do not; for example, the elevation of very heavy materials to a great height, cannot be affected by electrical attraction, because action and reaction being equal and in opposite directions, the upper parts of the atmosphere being so very rare, could not afford a reaction sufficient to draw up these materials from below, without being attracted downwards with a velocity altogether inconceivable, and we have no evidence of its coming down at all. But it is unnecessary to attack other theories; if the doctrine taught in this volume is true, it leaves no room for any other; it occupies the whole ground.

Neither is it necessary for me to explain every fact contained in the foregoing accounts. The reader who makes himself acquainted with the elements of the theory, will have but little difficulty in explaining all the principal phenomena. He must be careful, however, to make a distinction between the facts observed and the deductions of the observer. The deductions are often false, when the facts are true.

SECTION EIGHTH.

OF METEORIC RIVERS OR WATERFALLS.

192. On the morning of the 19th of June, 1838, a most destructive flood took place at Hollidaysburg, Pennsylvania. A paper published in that town, says, "About six in the morning the wind shifted, and soon after the rain, which, for three or four hours had descended from the north in sheets, abated, and not long after ceased altogether. The flood attained its greatest height about six o'clock in the morning, and very soon began to subside, and fell as rapidly as it had risen. No conception can be formed, by those who were not present, of the singular character of the flood. The storm, it is allowed, began about twelve at night, and continued with unabated fury, until after six in the morning. During that time the Juniata had risen about fourteen feet above its ordinary surface. About nine o'clock we were able to leave our dwelling, from the first floor, on horse back, and reached Hollidaysburg amidst the warm congratulations of the delighted crowd, and at twelve o'clock the river had returned to its usual channel."

On reading this account, I determined to visit the locality of the storm, as soon as my business in Philadelphia would permit my absence. I arrived in Hollidaysburg on the 26th of July, and remained there eight days, visiting the sides of the ridges and mountains every day.

The first ridge which I examined is west of the town about half a mile, at its nearest part. It runs east and west on the south side of the railroad. It is about eleven or twelve hundred yards long, pretty steep on the north side, and perhaps about two hundred feet high. On the east end it terminates pretty abruptly, and on the west not so much so. The whole northern side is covered with trees to the base, and on the top there is a cultivated farm.

On examining the northern side of this ridge large masses of gravel, and rocks, and trees, and earth, to the number of twenty-two, were found lying at the base on the plain below, having been washed down from the side of the ridge by running water. The places from which these masses started could easily be seen from the base, being only about thirty yards up the side. On going up to the head of these washes, they were found to be nearly round basins, from about one to six feet deep, without any drains of water leading into them from above. The old leaves of last year's growth, and other light materials, were lying undisturbed above, within an inch of the rim of these basins, which were generally cut down nearly perpendicular on the upper side, and washed out clean on the lower. The greater part of these basins were nearly of the same diameter, about twenty feet, and the trees that stood in their places were all washed out. Those below the basin were generally standing, and shewed by the leaves and grass drifted on their upper side, how high the water was in running down the side of the ridge; on some it was as high as three feet; it probably, however, dashed up on the trees above its general level.

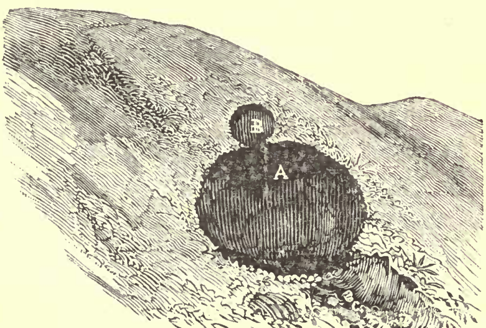
I have said that the basins were nearly of the same size, and nearly at the same distance apart, from forty-four to fifty yards. The one, however, at the west end of the ridge is an exception; it was only about six feet in diameter, and one foot deep, and exactly ten yards from the one next it to the east, or from centre to centre fourteen yards. Beyond this to the west the ridge tapers off and becomes quite low, and the basins terminate.

There is another ridge, called the Chimney Ridge, about the same length as this, though much higher and steeper, about south east from Hollidaysburg. This ridge runs a little north of east, and south of west. It has ten such basins on its northern slope, a little higher up from its base than the ridge first described. The one nearest the eastern end, however, is not round, as the others generally are; it is ninety feet long from east to west, along the ridge, and only twenty-one feet wide; and it has an outlet at each end, but none in the middle, and from these two outlets an immense mass of earth and rocks was carried down into the Juniata, which washes its base. The cut here was nineteen feet deep on the upper side, and six feet on the lower, of the middle space which was not washed out. And as this middle space had the old dead dry leaves, and other light materials lying on its surface undisturbed, it seems certain that this cut could not have been made by a mass of water of its own shape and size; it was, therefore, probably one spout of descending water, which wavered about, until it dug out the earth in the shape mentioned, discharging itself awhile at one end of the cut, and then at the other.

Above this cut there was no drain leading into it, and the dead leaves of last year's growth, and chips of wood which had been made by the axe, and other light materials, were lying undisturbed, as if the descending water had not even plashed up an inch above the perpendicular cut, nineteen feet deep.

The very great steepness of Chimney Ridge prevented me and Dr. Landis, who accompanied me in this examination, from going up to the several basins, along the side of the hill about fifty or sixty feet, or thirty or forty yards, measuring by the slope. But we measured the distances between the gullies below, and found them vary from about seventy to one hundred and twelve yards, with the exception of the most western one, which was quite small, and near to the one next it to the east, as had been the case on the first examined ridge. The quantity of water which fell in these ten columns was probably as great as fell in the twenty-three columns first examined. The ridge is about the same length, but much higher and steeper, and the descending columns of water were more than double the distance apart, and something higher up on the side of the ridge, and more irregular in their distance apart; and several seemed to have their east and west diameter longer than their north and south, while those of the first ridge were nearly all round. On neither ridge was there any drain above leading into the basins, nor any in between them, and the basins on both ridges were almost in a straight line with one another. And in all cases the basins were much deeper than the gullies formed by the water running from them. Indeed, these gullies were seldom deep enough to cut out the trees, but in all cases the trees were entirely removed from the basins.

On the south side of Chimney Ridge, nearly opposite, near the base, there is a small basin in a field where the side of the ridge is not too steep to be cultivated, and about two thirds of a mile from this last, near the top of the ridge, there is one of twenty feet diameter, and six feet deep, on a very moderate slope, perhaps about twenty degrees elevation from the horizon. This basin is round, with the exception of a small cut on the north eastern side, thus:



A, the basin; B, a hole of nearly equal depth; C, the earth washed out from below.

The small hole is about five feet in diameter, and four and a half feet deep. The earth is washed out below this basin on a level with its bottom, and there is a sugar maple of thirty-nine inches in circumference. yet standing erect on its base of wide-extended roots, about twelve yards from the basin where it must have grown, as there is no place below where the ground is washed sufficiently deep to have removed the tree. The force of water here was much greater than any one would have supposed, as the ground over which this tree was moved was very slightly inclining to the horizon. The ground was very hard on this side of the hill, and was but little furrowed below the basin in comparison with the great quantity of water which evidently fell.

The loose materials were lying undisturbed at the very brink of this basin, as in all the rest, and there was no drain of water above leading to it. The cause of this latter fact appeared difficult to understand until this last basin, with the small circular cut in its side, was seen. This cut was so distinct that there can be no doubt it was made by a descending column of water not greater in diameter than itself, and, as it could hardly be a distinct column falling in contact with a larger one, it seems almost certain that the large basin and the small circular cut at its side, were made by one and the same descending column, not more than five feet thick at its lower extremity, wavering about until it cut out a basin of twenty feet in diameter, and deviating from that boundary five feet, and cutting out the small perpendicular hole at its side. In this way all the other basins might have been cut by a column of water much less in diameter than themselves. This explanation seems the only possible one of the phenomenon in question. For if the column of descending water had been large enough to fill the basin, it seems certain that all light materials would have been driven away some distance from the upper brink.

Besides, the quantity of water which ran down the hill from these basins, in no case lodged the mud and leaves on the trees which were left standing in its path, more than three feet high, which would have been the case if the diameter of the falling columns had been as large as the diameter of the basins.

The immense quantity of water descending in one of these meteoric columns will be readily imagined when we consider that if they fell from a height of only four hundred feet, the water which fell in one second would be sufficient to cover a space twenty-four times the area of the transverse section of the columns ten feet deep, for the velocity of the water at the moment of reaching the earth would be nearly two hundred feet per second. If a column of only one square yard area should fall thus for even one minute, it would discharge water enough to cover an acre and a half of ground one foot deep.

It is impossible, at present, to tell from what height these columns fell after they were formed; but their velocity, when they reached the earth, was very great, as will more clearly appear from the following phenomenon.

Immediately after I arrived at Hollidaysburg, I went to an eminence and looked round on all the neighboring hills, and I discovered to the north west, near the top of Lehigh Ridge, in the midst of a very dense foliage, a naked space, to which I called the attention of several of the citizens who were with me. They all assured me that there was no field there, as the side of the ridge was quite too steep to be ploughed.

I determined to take the earliest opportunity to visit this spot, in hopes of finding something which might throw some light on the subject of my investigation. Accordingly, after I had examined the ridges mentioned above, the next day I took a horse, and, in company with a citizen of Hollidaysburg, who kindly offered to conduct me, rode to the foot of the ridge, and leaving our horses there, we ascended the side next to the east (for the ridge runs nearly north and south), and, with much labor and fatigue, reached the spot where the water had descended. It was near the top of the ridge, in the midst of an exceedingly dense woods, especially of undergrowth, so thick that it was very difficult to walk through it.

We found here a basin scooped out clean to the solid rock, about five and one half feet deep, and thirty-nine feet in diameter. The water, in cutting to this depth, had not spent all its force, and it rebounded and did not touch the ground again until it passed twenty-one feet down the slope of the ridge. When it struck the ground again, it cut out, in the earth which was very hard, mingled with stones, a space about forty feet long, three feet deep and fifteen feet wide, on the south side of its path, down the side of the ridge. This path was about as wide as the basin, but as the ground was very hard it was not torn out many inches deep, except in places where deep gullies and holes were formed quite down to the base of the mountain, which was probably about half a mile.

The few large trees which grew in the range of its path, were nearly all left standing; but all the small growth, of only a few inches in diameter, was either entirely torn out, or prostrated down the hill, and the leaves torn off, so as to cause the path to appear at a distance quite naked, and as if fresh ploughed.

As we returned to town by a different road, we discovered, in a field near the road, on the side of a hill facing the south east, seven small basins only a few inches deep, and ten or twelve feet in diameter, in a space of perhaps fifty or sixty yards in diameter. These basins were not in a row, as they were in all other places where more than two were near together. Nor were they nearly at the same distance apart, as the others were. Three of them were almost touching each other, and the other four were more remote. The earth, which had been cut out from these basins, had been carried down to the base of the hill by the water, over the top of the grass, without tearing up the grass itself. The hill was pretty steep to be cultivated, but it was, perhaps, not quite one hundred feet high. These basins were about half a mile from the base of Lehigh Ridge, on the south east.

On coming down south east, about three quarters of a mile further, we found, on the south west bank of the Juniata, three basins exactly in a row, and nearly of the same size, about three feet deep, twenty-one feet in diameter, and twenty-seven yards apart. These basins were almost exactly round, and their bottoms were washed out clean in very hard clay. It was only about thirty feet to the bottom of the bank from these basins, and there was but little ground washed out below. There was, however, drift lodged on the upper side of a tree in one of the paths, three feet high.

About a quarter of a mile from this, down the river, on the other side, there were two small basins so near together that their rims touched each other, and their paths united below. They are about three feet deep, and nine feet in diameter. There is a large stump of a tree between them, which is not washed out; and if this had not been there, it is possible these two spouts would have appeared but one, by the whole middle space being washed out. Was this one descending column, which wavered during its fall?

About a mile up the river, on this same north east side, we found, on the side of a very steep cliff, whose base was washed by the river, what may have been merely a *slide*, and it certainly would have been so esteemed, if the basins had not been discovered. Here there was no basin; the whole of the soil down to the solid rock was washed off clean, and the large trees which grew on it were washed out, and were standing on their lower ends, or roots, leaning against the steep cliff. The depth of the soil and earth washed off could not be estimated, as the debris was swept off by the Juniata.

The next day I visited Poplar Run, about five miles south west from Hollidaysburg. I found there, on the east side of a high ridge (a continuation of Lehigh Ridge, I believe,) about one third of its whole height from its base, a basin twenty-nine feet in diameter, and between three and four feet deep. The side of this hill was covered with so dense a growth of underwood that it was impossible to reach the basin, except by following the opening which the water had made in descending down to the base of the hill. This opening was quite similar to the one before described, of thirty-nine feet diameter, on Lehigh Ridge. The earth below the basin was not torn up very deep, as many of the shrubs had their roots still sticking in the earth where they had grown, though they were all prostrated, which made the ground look at a distance as if it were fresh ploughed. About half a mile east from this, on the west side of a very steep cliff bordering Poplar Run, were two basins not far up from the base of the cliff, about two hundred yards apart. These basins were small, and did not differ materially from those first described.

The great mass of water which fell in this remarkable flood, seems to have been confined to a space ten or twelve miles in diameter, having its centre a little south west of Hollidaysburg. The flood did not extend to any of the waters beyond the Alleghany, though I was informed by a gentleman who lives west of the summit level, eight or nine miles from Hollidaysburg, that there was a very hard rain there, and that it beat in violently on the north west side of his house.

On the east side of Hollidaysburg, probably from about fifteen to twenty miles, as appears by the evidence of Mr. McDowell, there was a hard rain, with most violent east wind, even a little earlier than the commencement of the rain in Hollidaysburg. I have not been able to learn in what direction the wind blew either on the north or south of the storm. At Hollidaysburg itself the wind was not remarkable; many could not even recollect that there was any wind; but several recollected some strong puffs, and also that the rain beat into their houses on the north east side. Many also remarked, and pointed out to their friends at the time, how strange it was that the clouds seemed to touch the ground, and to meet each other from the north and south. These phenomena were particularly noticed by many citizens of Hollidaysburg.

Hollidaysburg, June 19th, 1838.

193. Four o'clock, A. M., rain falling in torrents; lightning flashing with but little intermission; long and loud peals of thunder, with an occasional clap, that makes the earth tremble; wind from the east — increased until five o'clock, continued, with little variation, until seven, when the wind ceased, and about half an hour after, it ceased raining.

Wm. Hetherington.

Alexandria, Huntingdon Co., 20 miles east of Hollidaysburg, 16th Feb. 1839.

James P. Espy, Esq.,

Sir, — In answer to your inquiry, respecting the weather on the night of the 18th, and morning of the 19th June. On the night of the 18th June, about nine o'clock, the wind north east, very dark clouds from all points concentrated in a north west direction from this place, with a constant glare of lightning and thunder. Commenced raining here about two, A. M., and continued until daylight, not remarkably hard. On the morning of the 19th June, a gentle breeze from the west, air warm — cleared off about nine, A. M.

Most respectfully yours,

Charles Porter.

Hollidaysburg, July 30th, 1838.

To Mr. Espy,

Dear Sir, — In compliance with your request on Saturday evening, I will endeavor to describe, as well as my recollection will enable me, that part of the tornado which I witnessed, while on my way from Hollidaysburg, to Huntingdon, Pennsylvania, on the night of the 19th of June last. At about ten o'clock, my attention was arrested by the appearance of a thick darkness, which increased with astonishing rapidity; so much so, that in a few moments after I first observed it, it overspread the whole western heavens, as far as the eye could scan. I should have observed, that before I took any notice of this phenomenon, the night was remarkably calm and serene — with the wind at about south east, as nearly as I could distinguish, from the gentle breeze which was then stirring. At about half past eleven o'clock, the wind changed from south east to due east, the wind blew violently at this time, when it began to rain moderately. At about twelve o'clock, all was, as it were, the "blackness of darkness," the rain descending in torrents, and large sheets of very vivid lightning darting from south to north, in quick succession, accompanied with tremendous peals of thunder. The wind was still blowing from the east, when I left the deck of the boat to seek shelter from the violence of the tempest, which, at that moment, for terrific fury, entirely mocked all description. The above is as good a description, as my memory will permit me to give, not having charged it particularly with what I saw.

Yours truly,

Thomas C. McDowell.

This remarkable storm, with all its most wonderful phenomena, is not without example, both at home and abroad, as will appear from the following copious details.

Letter from Professor Silliman.

[Silliman's Journal, Vol. 15.]

194. We have passed the day in the Notch of the White Mountains, examining the scenery, the geology, and the ruins. The avalanches were very numerous; they were not, however, ruptures of the main foundation rock of the mountain, but slides[1] from very steep declivities; beginning, in many instances, at the very mountain top, and carrying down, in one promiscuous and frightful ruin, forests, and shrubs, and the earth which sustained them; stones and rocks innumerable, and many of great size, such as would fill each a common apartment; the slide took every thing with it, down to the solid mountain rock, and being produced by torrents of water, which appear to have burst like water spouts upon the mountains, after they had been thoroughly soaked with heavy rains, thus loosening all the materials that were not solid, and the trees, pushed and wrung by fierce winds, acted as so many levers, and prepared every thing for the awful catastrophe. No tradition existed of any slide in former times, and such as are now observed to have formerly happened, had been completely veiled by forest growth, and shrubs. At length, on the 28th of June, two months before the fatal avalanche, there was one not far from the Willey house, which so far alarmed the family, that they erected an encampment a little distance from their dwelling, intending it as a place of refuge. On the fatal night it was impenetrably dark, and frightfully tempestuous; the lonely family had retired to rest, in their humble dwelling, six miles from the nearest human creature. The avalanches descended in every part of the gulf, for a distance of two miles; and a very heavy one began on the mountain top, immediately above the house, and descended in a direct line towards it; the sweeping torrent, a river from the clouds, and a river full of trees,

[1] The words "slides" and "avalanches" do not seem appropriate.—AUTHOR.

earth, stones, and rocks, rushed to the house, and marvellously divided within six feet of it, and just behind it, and passed on either side, sweeping away the stable and horses, and completely encircling the dwelling, but leaving it untouched. At this time, probably towards midnight, (as the state of the beds and apparel, &c., shewed that they had retired to rest,) the family probably issued from their house, and were swept away by the torrent; five beautiful children, from twelve to two years of age, being of the number.

This catastrophe presents a very striking example of sudden diluvial action, and enables one to form some feeble conception of the universal effects of the vindictive deluge which once swept every mountain, and ravaged every plain and defile. In the present instance, there was not one avalanche only, but many. The most extensive single one, was on the other side of the barrier which forms the northern boundary of the notch. It was described to us by Mr. Abbot, of Conway, as having slid, in the whole, three miles, with an average breadth of a quarter of a mile; it overwhelmed a bridge, and filled a river course, turning the stream, and now presents an unparalleled mass of ruins. There are places on the declivities of the mountains, in the notch, where acres of the steep sides were swept bare of their forests, and of every movable thing, and the naked rock is now exposed to view. In the greater number of instances, however, the avalanches commenced almost at the mountain top, or high upon its slope. We pursued some of them to a considerable distance up the mountain, and two gentlemen of our party, with much toil, followed one of them quite to the summit. The excavation commencing, generally, as soon as there was anything movable, in a trench of a few yards in depth, and of a few rods in width, descends down the mountains, widening and deepening, till it becomes a frightful chasm, like a vast irregular hollow cone, with its apex near the mountain top, and its base at its foot, and there spreading out into a wide and deep mass of ruins, of transported earth, gravel stones, rocks and forest trees.

Mr. Wilcox, among other things, says, "On Wednesday, the weather being clear and beautiful, and the waters having subsided, six gentlemen, with a guide, went to Mount Washington, and one accompanied Mr. Crawford to the "Notch," from which nothing had yet been heard. We met again at evening, and related to each other what we had seen. The party who went to the mountain were five hours in reaching the site of the camp, instead of three, the usual time. The path, for nearly one third of the distance, was so much excavated, or covered with miry sand, or blocked up with flood wood, that they were obliged to grope their way through thickets almost impenetrable, where one generation of trees after another had risen and fallen, and were now lying across each other in every direction, and in various stages of decay. The camp itself had been wholly swept away; and the bed of the rivulet by which it had stood was now more than ten rods wide, and with banks from ten to fifteen feet high. Four or five other brooks were passed, whose beds were enlarged, some of them to twice the extent of this; in several the water was now only three or four feet wide, while the bed, of ten, fifteen, or twenty rods in width, was covered for miles with stones from two to five feet in diameter, that had been rolled down the mountains and through the forest, by thousands, bearing every thing before them, not a tree, or the root of a tree, remained in their path. Immense piles of hemlocks, and other trees, with their limbs and bark entirely bruised off, were lodged all the way, on both sides, as they had been driven in among the standing and half standing trees on the banks. While the party were climbing the mountain thirty slides were counted, some of which began near the line where the soil and vegetation terminate, and growing wider as they descended, were estimated to contain more than a hundred acres. These were all on the western side of the mountains. They were composed of the whole surface of the earth, with all its growth of woods, and its loose rocks, to the depth of fifteen, twenty, and thirty feet. And wherever the slides of the two projecting mountains met, forming a vast ravine, the depth was still greater.

Such was the report which the party from the mountains gave. The intelligence which Mr. Crawford, and the gentleman accompanying him, brought from the Notch, was of a more melancholy nature. The road, though a turnpike, was in such a state, that they were obliged to walk to the Notch house, lately kept by Mr. Willey, a distance of six miles. All the bridges over the Amonoosuck, five in number, those over the Saco, and those over the tributary streams of both, were gone. In some places, the road was excavated to the depth of fifteen and twenty feet, and, in others, it was covered with earth and rocks and trees, to as great a height. In the Notch, and along the deep defile below it, for a mile and a half to the Notch house, and as far as could be seen beyond it, no appearance of the road, except in one place, for two or three rods, could be discovered. The steep sides of the mountain, first on one hand, then on the other, and then on both, had slid down into this narrow passage, and formed a continued mass from one end to the other; so that a turnpike will probably not be made through it again very soon, if ever. The Notch house was found uninjured, though the barn adjoining it by a shed, was crushed, and under its ruins were two dead horses. The house was entirely deserted; the beds were tumbled, their covering was turned down, and near them, upon chairs and on the floor, lay the wearing apparel of the several members of the family, while the money and papers of Mr. Willey, were lying in his open bar. From these circumstances, it seemed almost certain, that the whole family were destroyed; and it soon became quite so, by the arrival of a brother of Mr. Crawford from his fathers, six miles farther east. From him, we learnt that the valley of the Saco, for many miles, presented an uninterrupted scene of desolation. The two Crawfords were the nearest neighbors of Willey. Two days had now elapsed since the storm, and nothing had been heard of his family in either direction. There was no longer any room to doubt, that they had been alarmed by the noise of the destruction around them, had sprung from their beds, and fled naked from the house, and, in utter darkness, had been soon overtaken by the falling mountains and rushing torrents. The family, which is said to have been amiable and respectable, consisted of nine persons, Mr. Willey and his wife and five children of theirs, with a hired man and boy. After the fall of a single slide, last June, they were more ready to take the alarm, though they did not consider their situation dangerous, as none had ever been known to fall there previous to this. Whether more rain fell now than had ever been known to fall before in the same length of time, at least, since the sides of the mountains were covered with so heavy a growth of woods, or whether the slides were produced by the falling of such a quantity of rain so suddenly, after the earth had been rendered light and loose by the long drought, I am utterly unable to say. All I know is, that at the close of a rainy day, the clouds seemed all to come together over the White Mountains, and at midnight discharged their contents at once in a terrible bust of rain, which produced the effects that have now been described. Why these effects were produced now, and never before, is known only to Him who can rend the heavens when he will, and come down and cause the mountains to flow down at his presence.

Yours, &c.

CARLOS WILCOX.

Letter of Mr. Theron Baldwin.

NEW HAVEN, AUGUST 14, 1828.

TO PROFESSOR SILLIMAN,

SIR, — The following notice, first issued at Montpelier, went the rounds of the papers in the course of the last summer.

MONTPELIER, JULY 10, 1827.

Avalanche. — A gentleman at Fayston, on whose veracity the most implicit reliance may be placed, has obligingly furnished us with the following account of an avalanche of earth or slide of the mountain in Lincoln, Addison county, on the 27th ult., occasioned by the late abundant and almost incessant rains. On the 30th of June, I went, in company with sixteen of my neighbors, to visit the spot so singularly marked by Providence, which I am now about to describe. I found the slide to commence near the top of the mountain, between two large rocks, which were stripped of earth, opening a passage of four rods wide, from which it proceeded in a south easterly direction, gradually widening for the distance of two hundred rods, to the south branch of Mill Brook, in Fayston. In its course, it swept every thing in its way, overturning trees by their roots, divesting them of roots, branches and bark, and often breaking them in short pieces. A number of rocks, judged to weigh from fifteen to twenty tons, were moved some distance. From where it entered Mill Brook, its course was in a north easterly direction, two hundred and eighty rods, the natural course of the brook being very small; but the channel, cut by this torrent, is now from two to ten rods in width, and, on either side, are large quantities of flood wood piled up very high, from fifteen to twenty rods of the lower part, it is blocked up across the channel in every direction; some of the trees are standing on their tops, and generally stripped of roots, branches and bark, and broken into many pieces. The pile, in some places, is ten feet high. Much of the timber is apparently buried several feet in sand and mud. One large birch tree was broken off square, measuring three feet nine inches where it was broken. One black ash was literally pounded into a broom, whose brush is seven feet long. The whole distance of these ravages is a mile and half, and the quantity of land thus suddenly metamorphosed into a barren waste, is twenty-five acres. The force of water must have been very great, at which, we cannot wonder, when we consider its probable depth. In some places, from appearances, it must have been thirty feet high. Some of the trees on the sides of the channel, were barked thirty or forty feet high, and there was mud on them at that height. T. B.

When this statement appeared, finding it difficult to conceive how, in those circumstances, causes adequate to the production of such effects could be put into operation, I resolved, should opportunity offer, to see for myself. Such an one presented itself in the month of May last. Accordingly, on a fine morning, in company with a single companion, I started from a place in Fayston, distant about seven miles from the slide, eager to behold this scene of desolation, and enjoy a ramble on the Green Mountains. Three or four of the last miles, lay through an entire forest, and our only guide was Mill Brook, which came dashing down through the wilderness. During our ascent, we found a number of streams emptying into this; but the marks of the flood were so evident, that we had no difficulty in deciding which to follow. The indications continued to grow more distinct as we advanced, till what for hours we had so eagerly looked for, broke upon our view; and we emerged from the forest into an astonishing scene of devastation. For a time, I could not credit my own eyes; and while standing in the midst of this desolation, found it almost impossible to bring my imagination up to the conception, that a physical force could be accumulated in that place, sufficient to accomplish the wonders with which I was surrounded.

I would here remark, that the statements of "T. B.," as to distances, &c., may be relied on as correct; for I was told by one of the sixteen who visited the spot (as above related), that they had a chain with them which was used in making the measurements. I conversed with a number of individuals in the vicinity, all of whom appeared to be well acquainted with the facts and ready to communicate them. The slide happened in the forenoon. The report was heard at the distance of several miles, and by some was thought to be an earthquake, by others a clap of thunder, although they could not account for its long continuance. I was told that it produced a very perceptible jar, similar to that of a peal of thunder. Had not the mountain been enveloped in fog, perhaps some favored mortal might have witnessed from an adjacent eminence the appalling spectacle of rocks and woods and waters roaring and rushing in frightful confusion down this precipitous descent. Various conjectures were afloat with regard to it, but as the fog vanished from the mountain, the true cause of the thundering and jarring was displayed to the view of the inhabitants upon the distant hills. It is visible from some of the adjacent towns, and has the appearance of a field recently ploughed. Fortunately, as it was a number of miles distant from any human abode, wild beasts alone were exposed to its ravages. A similar occurrence took place a few years since upon the same peak, but on a much smaller scale.

In its whole course, before reaching Mill Brook, it swept through a dense forest, mostly of hemlock and spruce, and took off the entire surface and every thing which it contained. The ground appeared to be as free from roots as if it had been tilled for fifty years. We observed some trees so firmly rooted in the rocks, that they could not be drawn out, which were pounded off upon a level with the surface of the ground, as if they had been but slender reeds. At some distance above the stream, the mass parted and left a few rods square of timber standing; but soon united again, and, rushing on in all its tremendous power, struck obliquely against the opposite bank of Mill Brook, with a concussion that must have shaken the everlasting hill. This bank rises very precipitously, and forms the base of another peak, which towers to a great height. At this place we judged the width of desolation to be twenty-five or thirty rods. As the frightful moving mass now struck against an immovable barrier, and its line of direction must be changed before it could follow the course of the stream, we should expect a greater accumulation of water, &c., &c., at this place, than at any other; and just below the point where this wreck of the mountain tumbled into Mill Brook, I should not think it exaggeration to say, that a perpendicular, raised from the bed of the stream as it now runs, to a line drawn across the channel, and connecting points on either side, where logs, sticks, &c., lie, in such a manner as to show that they must have been washed there by the current, would equal one hundred feet in length. It is certainly surprising how, even on a mountain as precipitous as this, such a mass, starting with a width of only four rods, could acquire sufficient momentum to carry before it an entire forest and rocks of an enormous size; but gravity created that resistless power, which could so many times change its direction and urge it down the stream in defiance of all the obstacles that opposed its progress, and where the elevation was constantly lessening. The principal and immediate agent was water, otherwise the mass would not have proceeded farther than where it struck Mill Brook, for it is easy to see, that a mass composed merely of trees and rocks and sand, however enormous its bulk or tremendous its momentum, could not have gone much farther than the first two hundred rods.

But how could the water accumulate on the sides of that precipitous mountain to the depth of thirty feet (as stated by T. B.), which I should think a moderate statement? This question arose as I stood gazing in astonishment, and I was strongly inclined to pronounce it impossible, notwithstanding facts which undeniably proved the contrary, that were staring me in the face. But it will not appear incredible, when we consider that the timber above Mill Brook was principally hemlock and spruce, the boughs of which would be extremely well calculated to produce an obstruction of the flood. A dam might easily be formed of the logs, boughs, rocks, and earth which composed this mighty moving mass, and the upturning of thousands of trees with the soil adhering to their roots, would greatly aid in effecting the object. And this appears to have been its *modus operandi* throughout the whole course. The ground was desperately disputed, but whenever a stop was given to the progress, the foaming torrent would accumulate behind, till it had gathered sufficient force to burst every barrier, — and again the huge pile proceeded, thundering down the mountain.

The forest seems to have been prostrated with as much ease as if it had been but a field of grain. The mass evidently went down in the wildest confusion; the trees sometimes erect, or sweeping around their branchless trunks in "horrid circles," would level tremendous blows at those upon the banks of the stream, as appeared by the bark frequently taken off at a great height; now their tops and roots alternately projecting forward, and again lying across the current, were shivered in an instant. They are left in considerable numbers throughout the whole course; some lying upon the banks, others in the channel, and wholly or in part buried in the sand and rocks. But the principal part of the timber swept from these twenty-five acres, lies piled in a confused heap, covering perhaps an acre of ground, and four hundred and eighty rods (one and a half miles) from the spot where the slide commenced! Here having already spent much of its force, and the mountain growing less precipitous, it struck into a cluster of firmly-rooted trees, and was compelled to stop. At this place it presents a perpendicular wall of logs, &c., across the entire channel, in some places ten or fifteen feet high. The upper end of the pile is buried beneath the sand and stones, and the stream now runs over the top. Perhaps those very logs will be dug out in after times as fossil wood.

Every thing in this mass bears the marks of the greatest violence. Almost every tree is as completely divested of its roots, branches, and bark, as could have been effected by man with the proper instruments. They are pounded and splintered, and broken into all imaginable shapes and lengths. We felt ourselves amply repaid for our labor. It is well worth the attention of the lovers of the marvellous, and especially of every one who has never witnessed such tremendous effects accomplished by the agency of water. I shall never more doubt that water is adequate to the production of any of those effects which are generally ascribed to the deluge. But I must confess, sir, that while attending your lectures upon this interesting subject, I always had a kind of incredulity with regard to this point, which went very far to weaken the force of conclusions fairly deduced from physical phenomena, of whose actual existence I could not entertain a doubt. And while standing upon that mountain, I realized the force of a remark which you have often made, that we can never be properly prepared to reason upon the phenomena of the deluge till we have taken the field and witnessed for ourselves the effects of those convulsions which have devastated the surface of our planet.

Yours, respectfully, THERON BALDWIN.

An Account of a Remarkable Storm which occurred at Catskill, July 26th, 1819.

[Silliman's Journal, Vol. 4.]

195. About half past three, P. M., three distinct clouds, dense and black, arose in the south east, in quick succession. A brisk shower followed. A fresh wind blew for a little period; but before four o'clock, a calm ensued, which lasted nearly an hour. A short suspension of the rain took place soon after five o'clock. The whole quantity which had descended between this time and the commencement of the storm, was considerable. About half past five, another dense and black cloud, accompanied by a fresh wind, arose from the south west. Shortly before the cloud reached the zenith, three vivid streaks of lightning issued from it, appearing like branches of the same flash. About the same time, or immediately after, a very thick and dark cloud rose up rapidly from the north east. They met immediately over the town. At this instant, a powerful rain commenced. The air soon became so obscure, that trees, buildings, and other objects, could not be discerned at the distance of a few yards. The obscurity did not appear to arise from a fog of the usual kind, but from the abundance of rain and the low descent of the clouds, which seemed to rest on the ground, or to hang a little above it. After the clouds met, the wind became very variable and blew for short periods from almost every point of the compass. At times, it came with so much force as to drive the rain in a very unusual manner through the crevices in doors and windows and the roofs of dwelling houses. Many houses which had never before been known to leak, at this time admitted great quantities of water. In several instances the wind suddenly abated, and a calm of a few minutes ensued. The lightning and thunder were unusually severe. The thunder frequently resembled a violent crash, and was as sud-

den and of as short continuance as the sound caused by the firing of a cannon, or by the snapping of a whip. The rain descended at times in very large drops, and at times in streams and sheets. During the storm, four or five intermissions, each of about eight or ten minutes, occurred also in the rain. In each instance, it excited a hope that the storm was over; but this hope was soon dissipated by the appearance of fresh torrents. The extreme violence of the rain terminated before half past six o'clock, though it continued to descend quite briskly until nine; and moderately until ten. It did not entirely cease until eleven. It is difficult to ascertain, with exactness, the quantity which fell during the storm. It seems probable, from facts mentioned hereafter, that it exceeded fifteen inches on a level. Some remarkable phenomena occurred in various places. At the Point, just before the clouds met, two sloops were observed, sailing before the wind, under a full press of sail, one sailing rapidly up the stream, the other more rapidly down. They met near the north end of the island, when the north east wind prevailed.

About the same time, the sloop Admiral started from the lower wharf for New York. At the moment of starting, two persons received slight electrical shocks from one of the three streaks of lightning mentioned above. Several panes of glass were broken in a store situated a few feet distant. One of these persons immediately after the shock, noticed strong luminous flashes or sparks on one of his arms, and felt a jar throughout his frame, and a sensation similar to that which is experienced when a hand or foot is asleep: the other felt a jar similar to that occasioned by a blow on the breast. No other injury was done to the store and none to the vessel. When the sloop had proceeded about three fourths of a mile, the air had become so obscure that those on board were unable to discern any object a few yards distant. At this time, another flash of lightning was discharged, about the sloop, and one of the persons before-mentioned, received a much more violent shock, which caused him to fall on the deck instantaneously. He was at this time drenched with water, and from this cause, probably, revived sufficiently to get to the cabin. In a short time he felt no other effects from the shock but a numbness which affected his arms for an indefinite period. While he lay on the deck, a gentleman standing by observed numerous flashes or sparks of light about his body, resembling those issuing from a firebrand when whirled swiftly round. They were accompanied by a crackling, snapping noise. Another person experienced a slight shock which occasioned such numbness in one of his arms as to prevent his using it for a short time. There was an iron spindle at the top of the mast, for suspending the colors, but no lightning rod. No injury was done to the sloop. Was that part of the cloud from which the lightning issued lower than the top of the mast?

Several, then on the deck, noticed that at this time the rain descended in streams and sheets. The gentleman above mentioned, states that at one time the water on the quarter deck accumulated so fast, from the rain only, as to be higher than his shoes.

A gentleman in the south store, at the Point, feeling much anxiety for his friends on the sloop, observed the phenomena of the storm with more exactness than any one with whom I have conversed. His account is as follows:

When the clouds met, they appeared to fall down on the river, between the store and Livingston's wharf, on the east bank. The cloud rested upon the water in such a manner that he could discover no space between them. As it came over, it appeared extremely dark at the bottom, and as white as a snow bank at the top. The air became so obscure, suddenly, that he was unable to see any part of a large perriauger which lay at his wharf, *thirty feet* distant, except that he could barely distinguish the poles. He particularly noticed that he could see no drops of rain, but the water seemed to descend in streams and sheets. The rain was most copious between a quarter before six and a quarter after six. In this half hour, he estimates the descent of water to have exceeded twelve inches upon a level. At an inn, thirty rods northward, the family were unable to see a sloop, lying in the creek at the distance of twenty rods. At another inn, close by, a man who stood for some time at the door, could not see any part of a barn only four rods distant.

Some time after the clouds met, two persons observed a water spout rising up from the river, and nearly opposite, with a broad bottom. It ascended with a whirling motion to the clouds, in the form of a pretty regular cone. The innkeeper noticed, some time in the afternoon, two other water spouts, from three fourths of a mile to a mile, up stream. They rose up in like manner, with broad bottoms, and terminated in points as they reached the clouds. They could not recollect at what time these phenomena took place.

The whole quantity of water which fell at the Point is estimated to have exceeded 15½ inches, on a level. I am persuaded this estimate is not too large. The rain extended with equal or greater violence, eight miles west from the Point, about three miles north, and seven miles south. On the east side of the Hudson, at a little distance, it did not descend with peculiar violence, or in an unusual quantity. At Athens, four miles north, it was far less severe than in Catskill; and at Cairo, ten miles west, it was light. Should we, then, estimate the whole tract on which the rain descended with peculiar violence, and in quantities never before known in that section since its first settlement, at eighty square miles, we should not, probably, be very far from the truth: and on this tract, I am persuaded, the water was full fifteen inches on a level. On a considerable part of the tract, we have reason to believe that it exceeded eighteen inches.

After describing a great many disastrous effects of the storm, Mr. Dwight goes on to observe that, in the neighborhood of Madison, the storm produced ravages not less remarkable. At no great distance northward from the village is a mountain, estimated to be six hundred feet perpendicular height, above the plane below. The south end of this mountain, which abuts upon the flat, which I mentioned as having probably been the bed of an ancient lake, is about one mile north north west from Madison church. The brow of the mountain here, is about half the elevation of the summit. There is at this place a ledge of horizontal rocks, running a considerable distance, and terminating abruptly, with a perpendicular precipice of twenty or thirty feet. The surface of the mountain descends for some distance back to this place. The water accumulating from above, poured down the precipice with such impetuosity, as to uproot all the trees in its course, down to the bottom, a distance of several hundred feet. The descent is rapid from the foot of the precipice to the bottom of the mountain. Throughout this distance a large ravine was formed. All the trees, and earth, and stones beneath, were washed away down to the solid rock, which lay below; and the whole mass except the trees was precipitated beyond the road, which winds near the base, upon a tract of arable and meadow land which it covered, as I was informed by Mr. S., a gentleman who had examined the ground with attention, to the extent of two acres, and to the depth of from six to ten feet. No water, if I am not misinformed, has been known to run in this place, heretofore. The descent of the water down the precipice occasioned a loud roaring sound, like that of distant rolling thunder, and excited no small astonishment at the distance of a mile.

On the eastern declivity of the same mountain, about two miles north of Madison church, a portion of ground about forty-five feet in length, and of about the same breadth, was entirely removed to the average depth of four feet. This ground, and all that adjoining to it, was previously covered with forest trees. The trees on this plat were all borne away. It seems remarkable that the excavation commenced suddenly, being of the full width, and depth, at the top. Neither was there any appearance of water having run from the grounds above, the decayed leaves and brush wood being in place. I have not examined this spot, but received the above particulars from a respectable farmer, residing in ths neighborhood.

In a south western course from Madison, distant from one to two miles, there is a high and sharp ridge, on which are several similar ravages. This ridge or mountain, which is upwards of four hundred feet in perpendicular height, above the plain below, was throughout, so far as can be seen on the eastern side, covered thickly with forest trees. The eastern acclivity is as steep generally, as the sharp roof of a dwelling house. The largest excavation is about two hundred and thirty feet wide at the bottom. Owing to the steepness of the acclivity, I could not measure its length, or the width at the top. I estimated the height to exceed three hundred feet. Tracing it from the bottom up the acclivity, about one hundred and fifty feet, it becomes forked, or divided into two branches, with a tongue of land between, which is covered with trees and shrubs. Below the fork, all the trees except two small ones, and the shrubs, were torn up by the roots, and carried by the force of the waters to the bottom. The ground, which was composed of soil of a moderate thickness, and of gravel and stones underneath, was washed away to the depth of four, five, or six feet in most places; and in some instances to the depth of ten feet or upwards. Below this are ledges of horizontal rocks, which have been laid bare to a considerable extent, and which were before invisible, rising tier above tier, and receding from below upwards. A great quantity of earth and stones were washed into the plane below, together with a part of the trees, and shrubs, and carried to the distance of ten, twenty, and in some instances thirty, rods. A much larger mass lies immediately at the bottom. The trees have been since chiefly removed. There are two or three other similar excavations not far distant. They may be seen at the distance of fifteen or twenty miles, on the high grounds eastward.

South of this ridge, at the distance of one or two miles, is another of less elevation, presenting on the eastern declivity similar ravages, in two or more places. These I did not examine particularly.

Generally, it may be stated that, within the limits of this township there are nine or ten similar excavations on the sides of the mountains, and sharp ridges, which were occasioned by this storm; that in each instance there exists no reason to believe that the water was accumulated from the neighboring grounds; that the ravages commenced suddenly, and are large and deep at their commencement; that the dead leaves and brush lying immediately above, and at the sides, do not appear to bear any marks of a change of position, nor to have been in any manner disturbed from the flowing of water; and that the configuration of the ground is in each instance such, as to forbid the supposition, that the water might have accumulated from the adjoining ground. Did a cloud highly surcharged with water, rest upon each of these places, till its contents were emptied? Did water-spouts discharge themselves here?

The following letter from Professor Park, of the University of Pennsylvania, is interesting, in connection with the subject of *Meteoric Rivers.*

PHILADELPHIA, October 5, 1838.

JAMES P. ESPY, Esq.

DEAR SIR, — In answer to your inquiries concerning the *slides* or *washes* of the White Mountains, which I have recently visited, I would unhesitatingly state my conviction, that they are produced, not by abrasion from the ordinary falling of rain, but by very sudden and copious discharges of water falling collectively from the clouds or regions of the air. Many of these washes commence so near the brow of the mountain, that there is no space above for the rain to accumulate, to produce such enormous effects. Neither do I think that the water could have been obstructed or dammed up on those steep slopes, so as to have acquired sufficient head and momentum to carry all before it, earth, rocks and trees, in one mighty deluge. A river falling from the clouds with resistless force, could alone account to me for such effects, and I believe this is the opinion of those writers who visited there soon after the melancholy disaster of 1826, when the Willey family were whelmed in an untimely grave. There are not less than thirty or forty of these slides on the west side of the Mount Washington range; but my remarks apply more especially to those on each side of the Notch, further south and east, which are much more numerous. Every thing is swept away there, down to the solid rock, even close to the summits, and where there is no basin above or behind to collect the falling waters. Very respectfully, yours,

ROSWELL PARK.

Notice of a Hurricane which ravaged the Island of Teneriffe, in the month of November, 1836.

[By M. S. Berthelot. Annales de Chemic. & de Phys. Vol. lviii. p. 209.]

Towards the tops of the mountains, the water-spouts fell on the culminating tops, tore away the soil, laid bare the rocks, razed the forest, and caused this mingled mass to roll through the windings of the ravines. This confused mass, on reaching the coast, with the overflowing torrents, sapped the fortresses situated at the entrance of the valley, and entirely destroyed them. In this manner, in the bay of St. Croix, an extensive fortification was swept away, with all its arms. And the strong castle of Candalasia, and one of those which defended the port of Orotava, disappeared, without leaving a trace. This terrible storm produced extraordinary events in the narrow passages in the mountain tops. I was myself struck by it in retracing anew that high point about a month after the event. Besides the rain, which did not cease to fall during twenty-four hours, and which a furious wind rendered more violent, it appears that these water-spouts fell on the points which offered the most attraction to meteors, such as the peak, and the adjacent country. The ground was turned up in a circumference of more than six hundred feet, and to a depth of from twenty to thirty feet in the circuit of the Canadas, which showed the action of the water in hollowing out the earth, by its being discharged with impetuosity. Mr. Alison, who went over the place at the time of his ascension to the Peak, in February, 1828, gave me a description of one of those excavations, which his guides showed as the effect of the storm. He perceived distinctly the trace of a water-spout; all the land had been inundated for the space of a circle, marked by furrows disposed in concentric circles, such as are sometimes produced by whirlwinds in a sandy soil.

This water-spout must have been enormous, since, according to the English philosopher, the waters at first collected in this bog, escaped afterwards by an inclined plane, and dug or scooped out a ravine, which extends even now as far as the valley of Orotava. After the account we have given, you can judge of the terrible effects of the storm.

The topographic details into which I have entered, were necessary, to cause the situation of the places to be well understood, which was more particularly the scene of disaster. We can thus appreciate better the chance resulting from the position of the valleys in relation to the superior regions, and perceive the reason of the causes which render them the principal scenes of the catastrophe, or which preserves them from its effects, — so we may understand how, in the district of Guiana, the ravines of Badajos and Chicayca become small rivers, carried off in overflowing the lands of the coast, a part of the vineyards of that valley; how, also, on the ravines of the Peak, the torrents ravaged the valley of Orotava, and rendered sterile places previously fertile. The barrancos of Tafuriaste, of an appearance so picturesque in its steeps, its cascades, and the groves of trees which ornament its banks, was covered with gravel, and levelled from the centre of the valley to its border. In the same district, the hamlet of Quiquira, situated on one of the arms of the great ravine of Harena, was swallowed up entirely; one of the sides of the volcanic projection of Realexo was swept off by the shock of the waters, and a whole portion of land disappeared; the impulse of the torrent increasing in strength with the inclination of the soil, carried off the whole suburb of the port of Orotava. On the sides of the bulk, comprised in the district of Taora and those of Icod and los Vina, torrents, precipitated from the culminating heights, dragged every thing before them; the village of La Guancha was taken off, with fifty-two inhabitants and three hundred animals; St. John de la Rambla, situated underneath, experienced great losses. In the bay of St. Croix, the torrent of Barranco Santo increased amazingly on the night of the storm; the impulse of the current became more violent at the mouth of the ravine, and was felt in the port, and was sufficient to send out a vessel on the point of landing.

Such were the effects of the storm which ravaged Teneriffe; as to the phenomena which was manifested in the duration, I shall relate the events communicated to me by two persons worthy of confidence. I shall have little to say from my own observations, as I was very much occupied from the time the storm began till it was over.

On the 6th of November, I was at La Laguna; it was some hours before the event. My friend, Dr. Savinon, professor of philosophy in the university of St. Ferdinando, advised me to remain with him, or to hasten to my home at St. Croix. I recollect his very words. "Since this morning," said he, "my barometer has been moving. Something extraordinary will take place in the air. Hasten and depart before the heavy shower." I followed his advice, and was convinced, on the road home, of the truth of his warning. The wind, which was at the S. W., before my leaving the doctor, had passed to the south, and seemed to incline to the east. This tendency in the wind to run over the parts of the horizon, unravelled at once the first evidence of a phenomenon, which I had twice witnessed in America. It was indeed the storm of the Antilles, it came with its forerunners, but this time, beyond its ordinary limits, it rushed on a region which I should have thought sheltered from its ravages. Masses of black clouds were gathered round the horizon, and seemed to ascend rapidly to the zenith; a long train of light clouds stretched from the south east to the north west, and the sky became darker every instant. The air was suffocating, transparent and sonorous, the wind came in squalls, accompanied by large drops of rain; however, the thunder was not heard, and this calm in the midst of the tempest was alarming. An hour had passed ere I arrived at the coast. The wind blew with violence all the morning; the sea, already rough, became more and more so in the afternoon; each surf shook the pier of St. Croix, and undermined the foundations. The wind went to the east, and there soon came a furious storm, accompanied with rain.

At three o'clock, two big ships broke cables, and were thrown on the shore; at nine o'clock, it was difficult to stand on the wharf, as the hurricane had so much increased in violence. A three-masted vessel from America, which had not had time to set sail, was thrown up against the end of the pier, and disappeared immediately. I passed part of the night on the sea shore, ready to help the vessels in distress; my mind was a prey to different impressions, in this continual agitation, wishing to see all for myself, and to judge of all, so as to lose nothing of this magnificent spectacle, and incapable withal, of any observation. Towards the middle of the night, the wind passed from the north east to the north west, the wind continued till the next day, and light broke upon new misfortunes. Accounts which reached us from all parts of the island, were distressing, and those which we had from the valley of the Orotava, where my habitation was, were still more alarming. I was tormented by a thousand fears; I knew not my friend's fate, I was told that my home was in ruins, and I trembled for my collections, my library, and my manuscripts. At the end of three days, I learned that nothing had suffered. Below is a fragment of a letter, from Mr. Auter, Professor of Mathematics, in the College of Orotava.

OROTAVA, November 10th, 1826.

The 6th of November, during part of the day, the heavens were covered with clouds, and the atmosphere was so clear and transparent, that objects could be distinguished at great distances; the air was very sonorous, the roaring of the waves was louder than usual; the refraction was very sensible, and seemed to raise the objects above the natural horizon. The wind blew from the south west, and towards night the sky was overcast with black clouds; the vapor accumulated on the height which surrounded the valley, and covered it with a dark veil. However, no sign of electricity was seen. The rain began at sunset, and soon fell in torrents; the wind went round to the northward, every instant the tempest increased. Towards midnight, the torrent threatened to overflow the town, the hissings of the wind on the prominent parts of houses, seemed mournful; the noise of the waves and the breaking of the water, seemed to unite to produce extraordinary effects. About two o'clock in the morning, I saw a light resembling an aurora borealis, but more bright. Streaks of light shot from the centre to the north of my house, which reached to the forty-second degree. The interposition of the convent of St. Francis, prevented me from seeing the focus of these phosphorescent lights, which lasted from seven to eight minutes, and disappeared again for a quarter of an hour. This luminous phenomenon was very interesting, and I watched to try to discover the cause. The light appeared again, more brilliant and more extended than before, and this time, the focus had changed its position, although concealed by the hills on the coast. This light disappeared again to show itself in different places. All continued to attract my attention, when I saw globes of fire in different directions. These new meteors crossed quickly in diameter, but they did not shoot out so much light as at first, they seemed to float on the waves; some seemed at several leagues from the shore, whilst the others shot streaks behind the elevation on the coast.

In turning to the south west, I perceived some at the foot of the Tygayga Mountains, about a league from the coast, and, no doubt, there were others, in other directions on the heights which overlooked the valley. These meteors disappeared at four o'clock in the morning; at six, the rain fell in torrents, and the wind, which had changed successively its direction, blew violently. I went out, desirous of learning if the meteors had been seen by others, and in fact, I learned that several persons had remarked the same fire. Some persons, who were so unfortunate as to be carried off by the torrents, but who had been saved, declared that they had seen great lights on the waves on which they were borne, and that every effort which they had made to reach the edge of the ravine, was accompanied by a burst of light, which appeared to rise from the water. To these interesting observations, I will add a note sent me by Dr. Savinon; I give it here literally. On the morning of the 6th of November, the sky was perfectly clear; towards mid-day, the wind blew from the south west, and though the squalls of wind were not yet accompanied by rain, the horizon was covered with heavy clouds. The wind continued all day and all the next night, although about ten o'clock in the evening, its impetuosity had diminished considerably.

The barometer stood at 28.532 inches, (English measure); however, at half past ten, the wind passed round to the north, then to the north west, with increasing violence, and at midnight, it became a furious storm, and the rain which accompanied this meteor, was so abundant as to change the ravines into dangerous torrents. On the 7th of November, at one in the morning, the barometer had fallen to 27.87 inches, and the strength of the wind had rapidly increased. It no longer came in squalls, it was one continued current, and such was its fury, that it tore up the largest trees, and sometimes even threw down entire forests. The tempest continued with the same violence till daybreak.

At seven in the morning, the barometer rose one tenth of an inch, and, from that instant, the storm began to diminish. At ten o'clock, the barometer again rose some thousandths of an inch, and the rain ceased almost entirely, but the wind continued to blow quite violently until night. At last, on the morning of the 8th of November, the barometer rose to 28.42 inches, and serenity was once more established in the atmosphere.

Mr. Alison's Narrative of an Excursion to the Summit of the Peak of Teneriffe, in February, 1829.

198. Fifteen minutes after leaving the last barranco, we crossed another, called Pilloni, which is rather more than 3,000 feet above the sea; and soon after, we entered the Barranco del Pino Dornajito, which is 3,410 feet above the sea; it is so named, from an enormous pine tree, that grew near the western side of the ravine. It is said, that this tree was full grown at the time of the conquest of the island, 360 years ago; thus, having stood the storms of so many ages, it was at last swept into the ravine, by the dreadful water-spout that devastated the island on the 7th of November, 1826. Although this tree is partly destroyed by its fall, yet it still measures 128 feet in length, and 30 in circumference. Under a precipice, in the middle of the ravine, is a small spring of water, with a wooden cross at the side of it; the temperature of the spring was 56°, but it appears to vary more than any other which I have examined, as in October, the temperature of the water was 65°.5. At the time of the beforementioned water-spout, a body of water, some hundred feet wide, and thirty or forty deep, fell over this spring and cross, without doing it the least damage; which the peasantry attribute to the Divine interposition, forgetting that the water, in falling from the height above, would form a curve, and effectually protect it from injury.

At ¼ to eight, A. M., we crossed the ravine, named Fuerrael Monte, and entered the Llanos de Gaspar (the plains of Gaspar). Here, vegetation became very scanty, and almost the only plant was Canarian thyme. But this spot is particularly interesting, from its being evident, that a considerable part of the water-spouts which deluged the island in November, 1826, had burst here, cutting the surface into a vast number of ravines, some of them of great depth. From the appearance of the surface, the columns of water which fell must have been very numerous; as in ten or twelve different places, the lava is cut into deep trenches, some of them fifteen and twenty feet deep, with the soil which was between them completely washed away by the spray or overflowing of the water. Many of these deep channels frequently converge into one, forming a destructive and overwhelming ravine.

Considerable bodies of water have frequently fallen upon the Canaries, and done some mischief by washing into the sea, the vegetable mould which so thinly covers the lavas. But the visitation of the 6th and 7th of November, 1826, was the most awful and destructive, both to life and property, of any of which the inhabitants have any tradition. My friend, Mr. Auber, of Orotava, has furnished me with the interesting details of the phenomena attending this water-spout, which I shall here subjoin. On the afternoon of the 6th of November, the wind, which was blowing strongly from the north east, veered round to every point of the compass, and ultimately established itself from the north; but at sea, a few miles from land, it was blowing a hurricane from the north east, and, in a moment, without any intermediate change, it blew as strongly from the south west. The sky became obscured all at once, by enormous masses of black clouds, which hastened the night sometime before sunset; but neither thunder nor lightning was observed. The rain commenced to fall in torrents towards ten o'clock at night, and the wind to blow with an overpowering impetuosity. At half past two on the morning of the 7th, Mr. Auber observed several globes of fire moving upon the sea, at various distances from the shore, whilst others remained stationary. One of them, from its position, appeared to be on the top of the Montaneta of Realejo, and caused him to suppose that that extinct volcano was going to threaten the valley of Orotava with an eruption; but he was soon undeceived, by observing that the globe moved about on the surface of the water like the others, and at some distance from the spot where he first thought it was situated. These luminous globes appeared to move towards the south west, and follow the direction of the waves. The light which they spread in the atmosphere, extended more than 45° high; and although he was three miles off, it was often sufficiently strong to enable him to read rather small print; but no detonation was heard. The number of globes increased from half past two o'clock till four, when they began to diminish. Mr. Auber, at one period of his observations, counted fourteen moving about at one time, but the glare of light which he perceived on his right, where the surrounding houses bounded his view, caused him to suppose their number to be much more considerable. Their duration was from one minute, to five or six, but seldom longer; and their apparent diameter was about the half of that of the moon at her full, when she reaches the zenith. When they had all disappeared, the darkness was extreme, and he could not see the neighboring houses; but a quarter of an hour afterwards, the reappearance of the same globes, or the formation of new ones, allowed him to see the island of Palma, though nearly sixty miles distant. The rain fell with equal force whilst these globes were appearing on the sea and after their disappearance. It was mentioned, that a globe of fire had fallen at the foot of the mountain of Tygayga, which bounds the valley of Orotava to the west, and that it had made a deep hole in the earth;—search was made respecting the truth of this assertion, but it did not lead to any positive result. I was likewise informed, that similar globes of fire were seen traversing the Llano de Gaspar, the spot which I have mentioned as bearing such evident marks of the effects of the water. My informant, who was a small farmer living near Tygayga, and almost on a level with the Llano de Gaspar, likewise added, "that all the heaths appeared to be on fire; and, at the same time, I saw a column of water several fathoms wide, move across the top of the valley." I will now resume the thread of my narrative to the Peak; and for the purpose of pointing out the devastation committed in 1826, I shall incur the risk of being thought tedious, by enumerating the ravines which I crossed at the spot, where the water-spouts appeared to have burst. The first was Barranco de Llano de Gaspar; it was of some depth, and exposed a stratum of basaltic lava, a species of puzzolana, of considerable thickness, and a brown volcanic mud resting on a bed of close black lava. A little to the west, were two new ravines, which united into one, at a short distance from the commencement, and formed the barranco, which did so much mischief to the port of Orotava. The next, was a new ravine, and is only remarkable for being the spot where you take leave of the luxuriant vegetation of the third zone, and enter that of the cytisus, which may be termed the fourth zone of plants. The surface here is a brown volcanic mud, mixed with small pieces of lava, forming a hard breccio or conglomerate, with a slight covering of vegetable mould, which in many places between the ravines, was completely washed away by the spray of the water.

Towards the south western extremity of the Llano de Gaspar is a spot named the Camina del Alto, where there is a stream of trachytic lava, that has separated at a short distance above, and formed a sort of half circle. The two streams are nearly destitute of vegetation. Another column of water appears to have burst here, and made three or four ravines, which converge into one a few hundred feet below. At half past eight o'clock, A. M., we entered a part of the inclined plane called Chasquitas Abaxo and Chasquitas Arriba. The ravines here are very numerous and some are so close together that there is hardly space sufficient to pass between them. Within a hundred yards, I crossed eleven, which were all formed in 1826, and in the upper part of Chastiquas Arriba the surface was cut into almost innumerable trenches of various depths, according to the force of the water, or the compactness of the lava.

When we gained the top of a rather steep acclivity, called Lorno de la Calavera, we met with a new barranco running into an ancient one of the same name as the hill; and about three quarters of a mile from it, we came to Barranco Juradillo, which is of an immense breadth and depth. At the spot where we crossed it, the torrent had divided itself into two branches, forming a sort of islet in the centre. The sides of the ravine were composed of various strata of lava and mud; the superior stratum was basaltic trap, occasionally inclined to a columnar formation; the second was a brown volcanic mud, about ten feet thick, below which was trap in laminar masses, volcanic breccia, and a sort of colorific earth. A short distance beyond Juradillo we passed on our left hand a hill of pumice, which had been cut down in a perpendicular manner to the depth of at least eighty feet, by the water-spout of 1826.

Moray Floods, 3*d August*, 1829.

199. The following documents were sent me by Graham Hutcheson, Esq., of Glasgow.

The following tables, viz. I., II., III., IV., V. and VI., are extracted from a book, entitled, "An account of the great floods of August, 1829, in the province of Moray, and adjoining districts, by Sir Thomas Dick Lander, Bart." These tables are numbered as in the book from which they are extracted.

No. I.

Extract of a Register kept at Inverness, by Matthew Adam, A. M., Rector of the Inverness Academy. Height about thirty feet, and distance from the sea about one mile.

1829.	Thermometer. 9½, A. M.	Direction of wind.	Barometer. 9½, A. M.	
Aug. 2,	61°	W.	29.94	Obscure; showers; wind and clouds from W., calm, with rain, evening.
3,	51°	N.	29.68	Obscure; light wind and heavy rain from N.; strong wind, clouds and rain from N. in the evening.
4,	55°	N.	29.65	Obscure; strong wind and rain from N., nearly calm in the evening. Memorandum, 2½ inches of rain fell here since the evening of Sunday, the 2d inst.

No. II.

Journal kept by the Rev. William Rennie Manse, of Fochabers, for Aug. 1829. *Latitude* 57.38. *Above the sea, eighty feet. Observations made about eleven o'clock, forenoon. Fochabers lies about twenty miles due east of Findhorn.*

1829.		Barometer.	Thermometer.
Aug. 3,	Heavy fall of rain all day; high wind,	N.W. 29.1	53
4,	Heavy rain in morning, cleared up at 12,	N.W. 29.5	50
5,	Serene and pleasant.	N.W. 29.7	62

No. III.

Journal of weather kept by Mr. Menzies, at Gordon Castle, for August, 1829. *Gordon Castle is only a mile from Fochabers.*

1829.		Thermometer. 8, A. M.	Barometer. 8, A. M.
Aug. 2,	W. Fair; wind moderate, warm all day.	61	29.6
3,	N. Heavy rain through the night and all the morning.	52	29.3
4,	N. E. Do. still continues.	51	29.2
5,	N. Fair; moderate breezes and sun.	57	29.6

No. IV.

Weather tables kept by Mr. Murdock, Gardener to his Grace, the Duke of Gordon, at Huntly Lodge. Huntly Lodge is to the north east of the mountains, and about twenty miles south of the sea, and about twenty miles south east from Fochabers.

1829.	Thermometer. At 10, A. M.	Barometer. At 10, A. M.	Barometer. At 10. P. M.
Aug. 2, W. Frequent heavy showers.	63	29.825	29.75
3, N. W. Tremendous rain all day.	51	29.45	29.3
4, N. Misty rain most of the day, 3.75 inches !!!!	56	29.5	29.75

On the 3d and 4th, the rain and flood tremendous. In August, 1829, 3¾ inches of rain fell between five o'clock of the morning of the 3d, and five o'clock of the morning of the 4th.

No. V.

Meteorological Table, by Mr. George Innes, Astronomical Calculator, Aberdeen. Aberdeen is about thirty-five miles south east of Huntly. And due east from the Cairngoom Mountains about thirty miles.

1829.	Barometer. At 8, A. M.	Barometer. At 9, P. M.
Aug. 2, W. to N. Cloudy with showers.	30.16	30.20
3, N. to N. N. E. Stormy; much rain; distant thunder.	29.28	29.30
4, N. Cloudy with rain.	29.74	30.13

No. VI.

State of the Winds at Findhorn, on the 2d, 3d, and 4th August, communicated by M. Thomas Davidson. Findhorn lies on the south side of the Moray Frith, about twenty-five miles north east of Inverness.

1829.			
Aug. 2,	9, A. M.	E. N. E.	Blowing fresh.
	1, P. M.	N. E.	Blowing hard.
	3, P. M.	N.	Blowing a gale.
	9, P. M.	N. to N. E.	A little more moderate; occasionally blowing hard, with showers.
3,	6, A. M.	N. E.	Blowing hard.
	1, P. M.	N. N.	Still blowing hard (I don't know what N. N. means.)
	6, P. M.	N. E.	Moderate breezes.
4,		N. E. to E. N. E.	All this day fine weather.

Extract from the Dundee Advertiser of the 6th of August, 1836; *for Mr. Graham Hutcheson, Glasgow.*

On Monday night (2d of August) we were visited by a storm of almost unprecedented fierceness, at this season of the year. Throughout the whole of the day the rain fell unceasingly, accompanied by a strong wind from the north east, (N. E.); but the storm did not commence in its grandeur till seven o'clock at night, when a thick gloom began to envelop the town. In a few minutes after, the wind blew a perfect hurricane, and the rain fell in torrents. Vivid flashes of lightning, accompanied with loud thunder, followed one another with a quickness which rendered it almost impossible to observe the commencement of one peal from the end of the other. The streets were entirely deserted. About nine o'clock the storm abated a little, but again commenced with tenfold fury about eleven o'clock, and continued till three o'clock on Tuesday morning. Several trees were blown down at the west end of the town. Many places are represented as being much flooded.

The accounts from all the surrounding towns are of a similar nature. No further mention of the 3d or 4th of August, 1829. [Extracted by Wm. Mennum, *Clerk.*]

Extracted from Leith Commercial List.

1829.	
Aug. 2,	W.
3,	W.
4,	N. E.

Glasgow. Extracted from my own [Mr. Hutcheson's] Register.

1829.		
Aug. 2,	A very little rain.	Wind not marked at this period, but probably the same as at Greenock.
3,	Rainy.	
4,	"	

Greenock. Extracted from the Greenock letter. Registered in the forenoon.

Aug. 2,	W. N. W.	Fresh breezes and clear weather.	Rain not stated, but probably the same as at Helensburgh, 4 miles to the north of Greenock.
3,	N. W.	Breezes and cloudy weather.	
4,	N. E.	Moderate breezes and cloudy weather.	

Helensburgh, four miles north of Greenock. From Dr. Gibbs's Register.

Aug. 2,	Showery,	Wind not stated in the register at this time, but probably the same as at Greenock.
3,	Heavy rain.	
4,	Dark and cloudy, but dry.	

Liverpool. Extracted from the Liverpool letter. Registered probably about 2, *P. M.*

Aug. 2, N. W.
3, S. W.
4, N. During last night, (evening of 3d August,) we had a very heavy gale from N. N. W.

Passages Extracted from "An Account of the Great Floods of August, 1829, *in the Province of Moray, and adjoining Districts, by Sir Thomas Dick Lauder, Bart.*

Page 1. The heat in the Province of Moray, during the months of May, June and July, 1829, was unusually great, and in the earlier part of that period the drought was so excessive as to kill many of the recently planted shrubs and trees.

Page 3. The deluge of rain that produced the flood of the 3d and 4th of August, fell chiefly on the Monadhleadh mountains, rising between the south eastern part of Loch Ness, and Kingussie in Badenoch, and on that part of the Grampian range forming the somewhat independent group of the Cairngorums.

Page 4. At Kirkwall, in Orkney, there was a violent storm of wind and rain on Monday, the 3d of August. A similar deluge was experienced at Wick, and much damage was done in the parishes of Watten, Halkirk and Latham. In Sutherland and Ross-shire, both lying to the westward of the line I have described, as well as the country to the north of Loch Ness, little or no injury was sustained. But the river Foyers, deriving its source from the very mountains that first received the column of drifted vapor, was so highly flooded as to destroy Whitebridge.

The rivers Nairne, Findhorn and Lossie, were all more or less affected by the flood, exactly in proportion as they were more or less connected with the mountains in question. That part of the Spey which is above the line I have marked, was hardly swollen at all; while at Kingussie, it and its tributaries were elevated to an unexampled height; and the Deveran, the Don, the Dee and the two Esks, were each of them operated upon in a similar ratio.

Page 5. But the question as to the quantity of rain is settled by the accurate observations of Mr. Murdoch, gardener to his Grace the Duke of Gordon, at Huntly Lodge, who informs me that $3\frac{3}{4}$ inches of rain fell between five o'clock of the morning of the 3d and five o'clock of the morning of the 4th of August: that is to say, that taking the average of the years from 1821 to 1828, inclusive, about one sixth part of our annual allowance of rain fell within these twenty-four hours; and if such was the fall at so great a distance from the mountains, the deluge that descended on them must have been so enormous as to lead us rather to wonder that a flood, even yet more tremendous in its magnitude and consequences, did not result from it.

Page 178. The river Spey holds the third place among Scottish rivers. It rises about sixteen miles south from Fort Augustus, has a run of about ninety-six miles, and drains not less than 1300 square miles of country.

The Spey and its tributaries above Kingussie were but little affected by the flood of the 3d and 4th of August.

Page 43. The spouts of rain on the 3d and 4th converted every dry scar on the mountain faces into a torrent, which soon cut it into a ravine and covered an acre or two of the slope below with huge stones and heaps of gravel, to the depth of many feet. In two places, where the hill side was formerly quite entire, it was torn open, and fragments of detached rock, eight or ten tons in weight, were thus dislodged and thrown down. The rock and hills were every where sheeted with cataracts, whilst these huge masses were tumbling headlong from their beds with a thunder even louder than that of the river.

Page 64. The green slopes of the hills were converted into naked precipices.

At Gordon Castle, mouth of the Spey, north of the storm, min. barom. 29.20.

Page 178. The western boundary of the fall of rain seems to have been about the line of the river Calder, (a little south east from Loch Ness,) which enters the Spey from the left bank. The deluge was tremendous, accompanied by a violent north east wind and frequent flashes of lightning without thunder. The barometer sank very little, but this was attributed to the direction of the wind.

Page 38. A little north east from the river Calder, high up on the Findhorn, the landlord of the inn told me that there were showers on Sunday, the 2d, and during the night; but that the serious rain did not come on till Monday morning, about eight o'clock, when the water fell from the heavens more tremendously than he had ever seen it fall before. Here, as elsewhere, it was accompanied by a violent north east wind, and it continued till about four o'clock on Tuesday evening.

Page 239. In the afternoon of the 1st, Mr. Skinner, who lives at Drummin, immediately above the junction of the Livat with the Spey, (near the centre of the storm,) observed an unusually dark cloud on the top of Cromdale hill. It was so remarkable in its appearance that it excited universal notice. The barometer stood with him on that day at 30, but fell gradually till the 3d, when it stood at 28.2.

Page 354. (Near the head of the Dee—southern part of the storm). The rain on the northern mountains was infinitely more tremendous than that which fell in the valley; and whilst the tributaries from that quarter were swollen to an unparalleled height, those from the south, in the Bræmar district, were not more raised than they are every year by spring and autumn floods. Instances of outbursts of subterranean water were frequent in the northern mountains. The red granite hill of the Muckle Glashault, nine miles to the north west of Invercauld, is about 3000 feet high and of steep ascent on all sides. . . . . On the north side, and about one third of the way from the summit, no less than fifteen or sixteen of these openings have been made, varying in breadth from thirty to forty yards. Each of these appears to have had an immense column of water issuing from it, which has cut a track for itself to the very base of the mountain.

Dr. Robertson, of Crathic, concludes, from the appearances, that the water burst from the bowels of the earth in repeated jets, rather than in one continued stream. None of those appearances existed before the 3d and 4th of August. They are by no means confined to Muckle Glashault, being observed, of greater or less magnitude, by Dr. Robertson, in all the hills he had an opportunity of examining.

Page 352. At this place it rained a little on the evening of the 2d, and throughout the morning of the 3d there were heavy intermittent showers, with strong gusts of wind from the north west; and the barometer never fell below 29½.

Page 307. The schooner Pursuit, at the mouth of the Spey, was driven from her chain out to the bar, by the fury of the water, and her salvation was effected by her being kept dreadfully balanced between it and the opposing force of the violent north east wind.

200. In examining the phenomena here recorded, it is worthy of particular notice; 1st. That all these meteoric rivers fell on the sides of hills or mountains.

2d. That the magnitude of these rivers seems to be in general in proportion to the size of the mountains, or at least to the height of the points where they first touched the earth.

3d. Wherever the direction of the wind is mentioned, it is towards the storm. It blew towards Hollidaysburg, both on the east and west; two currents of air met in the Hudson, at Catskill; a very strong north east wind blew towards the Moray hills, on the north east side of the Moray floods; and at Greenock, north west, and at Liverpool south west, and at Leith west, in the same storm; and in Teneriffe the wind, which had been south west, changed round suddenly at the beginning of the storm, on the east side of the island, and blew a gale from the east, and on the north it changed round suddenly, and blew a gale from the north; whilst in the interior part of the island, at Laguna, the wind continued yet for many hours longer from the south west.

4th. The clouds were seen to meet from three directions; at Hollidaysburg, in three directions; at Catskill, in two directions; in New Hampshire, "at the close of a rainy day, the clouds seemed all to come together over the White Mountains, and at midnight to discharge their clouds at once in a terrible burst of rain."

At Teneriffe, "the clouds came rapidly together from every part of the horizon."

5th. The clouds either touched the ground, or covered the mountains.

6th. The barometer fell, near the centre of the Moray storm, 1.8 inches, whilst both on the north east and north west, and south west side, it fell very little; and in Teneriffe, in the interior of the island, the barometer sank from 28.532 to 27.870, in a few hours; when, at the same time, the wind on the east was blowing a most violent gale from the east; and on the north a most violent gale from the north.

7th. All these storms took place at a time of year when the dew point may be high; for even in November the dew point may be high in Teneriffe.

8th. These storms appear to have been stationary over a very limited extent of territory, and to have continued longer in proportion as they were larger.

When such astonishing phenomena as these are presented to our minds for the first time, and satisfactorily proved to be true, it is natural and proper for us to inquire how these things can be.

By what power, hitherto unknown, is this mighty mass of water suspended until it accumulates so as to become "a river from the clouds"?

The answer to this sublime question may be stated in a few words.

The wind, which blew inwards, as it did with great violence, on coming to the side of a mountain or hill, must necessarily ascend; in ascending it would carry up drops of rain to a height proportionate to its velocity; when these drops became so numerous and heavy that they could no longer be forced upwards, which they would soon do, by the constant accession which would be made to them by the condensing vapor in its ascent, whether the sheet of water thus formed in the air were thick or thin, on beginning to descend, it would naturally break up into parts, and in descending each part would naturally form itself into the shape of an inverted cone, or rather trumpet, with the little end downwards. The latent caloric evolved by the condensing vapor, it is now known, is sufficient to expand the air in the region of the cloud between six and seven thousand cubic feet for every cubic foot of water that is generated by the condensing vapor, after making due allowance for that condensation, and thus furnishes an adequate upmoving power.

It would be vain to speculate on the height to which these masses of water are carried up. Perhaps the distance at which the meteoric rivers fall apart, and other phenomena attending their fall, may yet furnish data sufficient to bring the calculation within the power of mathematics.

It would appear from the following fact, that a river of hail sometimes falls from the clouds; and of course it must fall from a great height, even above the region of perpetual congelation.

"On Tuesday, May 4th, 1697, (at Hitchin, in Hartfordshire,) about nine o'clock in the morning, it began to lighten and thunder extremely, some great showers intervening; it continued till about two o'clock in the afternoon, when on a sudden a black cloud arose south west of us, the wind being east, and blew hard; then fell a sharp shower, with some hailstones. I measured some of them, seven or eight inches about; but the extremity of the storm fell about Offley, where a young man was killed, one of his eyes struck out of his head, and his body all over black with bruises. The tempest was such when it fell, that in four poles of land, from the hills near us, it carried away all the staple of the land, leaving nothing but chalk; the flood came down, spreading over four or five acres of land, rolling like the bay of Biscay; and, which is very strange, all this within the compass of one English mile. I was walking in my garden, which is very small, perhaps about thirty yards square, and before I could get out it took me to my knees, and was through my house before I could get in, which I can modestly speak was in the space of a minute, and went through all like a sea, carrying all wooden things like boats on the water. The greatest part of the town being under this misfortune; the surprise was so great, that we had scarce time enough to save our wives and children. There fell some thousand cartloads; I saw them four days after, and if the beds of hail had not been broke by people's coming, and trampling of horses, it might have lain till Michaelmas. They have been measured from one to thirteen or fourteen inches, certain; some people talk largely of it, seventeen and eighteen inches; but the other is certain truth. The figures of them are various, some oval, others round, others picked, and some flat."

There can be no doubt that the force which held up these hail stones until they became so numerous as to form "a *river of hail* from the clouds," which "rolled like the bay of

Biscay," on reaching the earth, was the same in kind as that which formed the *rivers of water* from the clouds. Indeed, if any violent hail storm were to stop its motion along the surface of the earth, for even fifteen minutes, as this storm probably did on reaching the hill on whose side it fell, it would throw down just such a mass of hail as fell at Offley.

It would appear, indeed, impossible that many thousand times as much water should be collected into one column in a few minutes, in the air, as a column of the atmosphere of the same diameter contains in vapor, even if it all could be condensed.

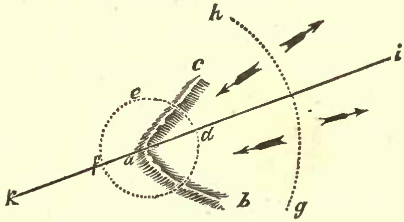
But this difficulty will vanish when we consider that if the barometer should only fall one inch and a half in the middle of one of these land spouts, the air would spout up in it with the velocity of six thousand yards per minute; and it is known by experiment, if the dew point in this case should be about 71°, which is common in the summer, that a sufficient cold would be produced by the expansion of the air in rising to this height, even after making allowance for the latent caloric given out by the condensing vapor, to condense one half the vapor contained in the air. Therefore, with the assumed velocity of the upmoving column of air, $7\frac{1}{2}$ times as much vapor would be condensed in fifteen minutes as one of these columns contains; or about enough to cover a space equal to the base of the upmoving column, forty-one inches deep. Now if this ascending spout of air should not be perpendicular, it would throw the drops of rain or hail which might be formed by the condensing vapor in its upward motion, all out on one side, and these drops, in descending, would evidently tend inwards towards the centre of the falling mass, because *there* the drops would meet with less resistance to their descent by following others which had preceded them.

Thus a column of descending water or hail might be formed many thousand times less in diameter than that of the ascending spout of air.

This column of hail, falling from so great a height, (for it must have been carried up beyond the region of perpetual congelation,) might well "carry off all the surface of the ground, and leave nothing but the naked chalk, covering four or five acres of land below, and rolling like the bay of Biscay." It may easily be calculated, however, that the descending column, on reaching the earth, could not, if it was solid, have had a diameter of two poles, and therefore its lower end must have wavered about as the columns did in the Hollidaysburg storm, so as to cut out a space very much larger than itself.

This was probably the case also in that basin which Mr. Alison describes in the Teneriffe storm, as being six hundred yards in circumference, and thirty feet deep, with furrows cut in concentric circles.

The stationary character of all these storms is not a little remarkable, especially as it is now known that tornadoes in this country always travel towards the east, or in some eastern direction. This anomaly may be explained in the following manner.



Let *a b* and *a c* be two mountains, of moderate height, butting up against each other in the south west, and let the circle *d e f* represent the area of a storm moving along the line *k i*, from south west to north east. When the centre of the storm reaches the mountains the barometer will stand lowest at the mountains, and be above the mean at some distance from the borders of the storm, in consequence of the rapid outspreading of the air in the upper part of the cloud in the region of the storm, and this effect will be felt, especially in the north east of the storm, because the upper region of the atmosphere in this part of the country moves generally to the north east. Let *h g* represent the line, or part of the annulus, where the barometer stands highest to the north east of the storm, then will the wind blow both ways from that line, and as it approaches the centre of the storm at *a*, it will increase very much in violence because the barometer is low there.

When this wind reaches the mountain it will be obliged to rise even before the centre of the storm has reached there, and in rising will form cloud. Now this formation of cloud will soon bring the centre of the storm to the east side of the mountains, for the cloud which rises on the west side will be pressed over towards the north east by the upper current in the atmosphere. Thus will the centre of the cloud be held constantly over the region just east of the mountain.[1]

We are now prepared to answer a question which naturally arises here. Why does the rain cease? By casting the eye on the figure, it will be perceived that the air blows in opposite directions from the annulus *h g*, and of course the atmosphere sinks down there. Now as soon as the dry atmosphere of the upper regions reaches the earth the supply of vapor is cut off from the storm, and the storm ceases. This is one way in which the rain might cease, as it does

[1] If the mountain against which the wind blows is immoderately high, as the Andes or the Himalaya, it is manifest that the rain will fall on the windward side; but it would be out of place here to assign the reason why the wind blows for four or five months in the summer against the south west side of the Himalaya mountains.

round a volcano. Or perhaps it might cease by the widening out of cloud above in the form of a mushroom, and thus form a general rain, which of course will come under the general laws which govern storms in their motions along the surface of the earth.

SECTION NINTH.

OBJECTIONS TO THE THEORY, WITH ANSWERS.

Professor Olmsted's Objections, with Replies.

201. In a public lecture, delivered by Professor Olmsted in Clinton Hall, New York, various objections were urged against my theory, which I propose to answer, as briefly as the nature of the subject will admit.

After making some preliminary remarks, which were not connected with the correctness or incorrectness of my theory, the Professor proceeded to state, without controverting some of the principal chemical laws on which my theory is founded, for example, that about 1000° of latent caloric are given out when vapor is condensed into water, whether it is condensed in water or air; that if air is expanded by diminished pressure, it became colder, and that to a great degree, as he proved by the Chemnitz experiment, where air is let out after being under great pressure, when it produces a cold sufficient to freeze drops of water which were in it, and of course to condense much of its vapor into water. These principles, then, are acknowledged, and the quantities, as I state them, not denied. It is contended, however, that "my deductions are neither conformable to the laws of heat nor to the phenomena of nature."

The Professor says that "the latent caloric, when evolved during the formation of a cloud by the condensation of the vapor, either stays where it is, or passes away into space by radiation. If it stays where it is, it would prevent the condensation of vapor altogether; and if it is radiated off into space as fast as it is evolved, it is not there to do the work assigned to it by me. In fact, that my proposition is absurd and impossible; that I speak of a great cold to condense the vapor, and a great heat to expand the air in the cloud so much as to make it greatly lighter than air surrounding the cloud at the same height." To avoid this dilemma, the Professor says "the caloric evolved during the formation of cloud is actually radiated off into space; at least, so much of it as to prevent the cloud from being warmer than the surrounding air at the same elevation."

The answer to this objection is very easy. First, it is known from the dew point, that if air is cooled down by expansion from diminished pressure 30° below the point of condensation, a large portion of its vapor will be condensed into cloud. Now, if air goes up in a column six thousand yards high, it will expand, by diminished pressure, sufficient to produce 30° of cold, even if it should receive latent caloric enough to heat it 30°, for without this latent caloric, it would be more than sixty degrees colder on reaching that height; so it is not necessary to the formation of cloud of great density that any of the caloric evolved should escape into space by radiation during its formation.

This will not be denied by any one who understands my theory well enough to repeat the numbers just mentioned. He will perceive that the air, in going up six thousand yards, has been subjected to a cooling process, which would have reduced its temperature more than 60°, if no latent caloric had been given out; but, in consequence of the latent caloric evolved, it will be cooled only about half that quantity, and of course will then be about 30° warmer than the air surrounding the cloud at the same height; consequently it will be about $\frac{30}{480}$ lighter.

Besides, what right has the Professor to take it for granted that all this great quantity of caloric is radiated off into space as it is evolved, in the formation of cloud? It is a mere hypothesis, without any experiments to support it. Nay, it is contrary to experiment; for if steam is let out of a steam boiler into the air, when it makes cloud, we know it gives out no more caloric to the air than an equal quantity of vapor in the atmosphere gives out when it forms cloud; for the sensible and latent caloric of steam, when added together, is a constant quantity, equal to 1242° Fahr., as appears by the beautiful experiments of Professor W. R. Johnson, of Philadelphia. At least, he has proved that the latent caloric of steam, at the temperature of 212°, is about 1030°; and it is generally admitted that the *latent* caloric of steam diminishes as the *sensible* increases.

But all this doctrine aside, it is proved by experiments with the nephelescope, that only about one half as many degrees of cold are produced by a given expansion when cloud is formed, as when air so dry is used that no cloud is formed. This experiment was not even mentioned by the Professor, though it was brought forward prominently by me as proof positive and undeniable, of the entire truth of my theory, and that, too, independent of all knowledge of the physical laws of latent caloric, and the specific caloric of air.

Before my theory is proved *false*, that experiment must be refuted. But the Professor exultingly said, that "the experiment which I adduced to prove that cloud is warmer than surrounding air, proved his doctrine of radiation, — namely, the etheriscope of Leslie; when that instrument was turned towards a cloud the thermometer rose, and when turned away from the cloud, towards the clear sky, the thermometer fell."

I will not argue this point; the whole scientific world will agree with me that the thermometer rose in consequence of the superior heat of the cloud. It is true the experiment proved that the cloud radiated; but it proved likewise that it did not radiate all its caloric of elasticity as fast as it was evolved, or it would not have so much left, to radiate for hours after the cloud was formed.

Besides, there was no answer attempted to be given to the observations of Sausseur, that when he was enveloped in a cloud rising up to him on the side of a mountain, his thermometer rose higher than it was in the open sun.

Nor was there any mention made of Mr. Durant's and Gay-Lussac's observation, of a similar nature, as they passed through a cloud in a balloon. But what shall I say of the Professor's altogether neglecting to mention the proof which I brought forward, by an experiment with the nephelescope, that the air is not only warmer when a cloud is formed by the cold of expansion from diminished pressure, than it would be with the same expansion when no cloud is formed, but also showing the exact number of degrees it is warmer. This experiment lies at the very foundation of the theory, and, as it was not denied, it was tacitly admitted. If so, the foundations of the theory have not been shaken.

There is one part of the professor's strictures I would willingly pass by unnoticed, if justice to my subject did not demand a reply. The Professor said that my experiments proved nothing as to the formation of clouds in nature, for in my experiments, the air was first condensed and then rarefied, and though a cloud is formed in the nephelescope, yet it would not be formed so by nature, for she never condenses first. Now, one of two things is certain from this declaration; either the Professor was ignorant of the common experiment with the air pump, in which a dense cloud is formed in a receiver by suddenly exhausting a portion the air from it, and that, too, without any previous condensation; or he wilfully avoided the main question, knowing the statement which he made was a mere evasion. It is not for me to say which was the fact.

I am willing to suppose the Professor misunderstood me when he stated that I drew the deduction, that because cloud was formed in the nephelescope when the air expanded, therefore all clouds in nature were so formed. This, I never stated, either in writing or in my lectures, as a deduction from this experiment alone. The deduction which I drew was that, if it could be demonstrated that currents of air rose up from the surface of the earth to a certain height, depending on the dew point, and temperature of the air at the time, cloud would be formed, and that too on the very principle on which they were formed in the nephelescope, by the cold of expansion from diminished pressure; whether all clouds are so formed or not, depends on other proof. It did not appear to me very clear, whether the Professor acknowledged there would be any cold produced in the air from diminished pressure, even if a current of air should ascend, unless it had been previously condensed as in the nephelescope and at the Chemnitz fountain; for he said a *man* would feel cold if taken up to a great height without expanding from diminished pressure. This argument does not seem to me to require an answer.

Professor Olmsted did not do me justice when he said that I had stated in my lecture as an *argument* in favor of the truth of my theory, that scientific men were generally against me. I did not mean to be so understood.

The Professor had stated in a previous lecture, that "as I had failed to convince scientific men of the truth of my theory, I had appealed to the people," who, he insinuated, were incompetent to decide the question. In my lecture, I thought it but right to *acknowledge* that a large portion of the scientific world were against me, and mentioned Sir John Herschel as among the first men of the age; but I denied, that that settled the question; and I immediately attempted to shew, by reasoning so plain that the *people* could understand it, that the argument which Sir John brought forward as conclusive against my theory, was one of irresistible power in its favor. And I think we may safely conclude, it was satisfactory to Professor Olmsted himself, as it was not attempted to be impugned; though it was one which I dared my opponents to attempt to invalidate.

It is true the Professor said, "my chimney would not draw because the *bricks were all out;*" that is, even if the cloud is as much lighter than the surrounding air, as I say it is, still the air would not run in below and upwards in the middle and outwards above. This being contrary to the known laws of dynamics, and to the doctrine taught in all the books, that air which is rarefied by heat will ascend and other air rush in to take its place, or rather press it up by its superior gravity, I suppose it was intended for wit and not for argument, and as such needs no answer from me. I will only say the Professor's figure of a narrow streamlet or cylinder of air, confined to a very narrow space under the centre of the cloud, did not convey a correct idea of the doctrine which I teach, namely, that the air flows in on all sides, sloping upwards from beyond the borders of the cloud, not only at the surface of the earth, but up to the base of the cloud itself, and sometimes a little above, when the cloud becomes of great perpendicular altitude, from its summit to its base, as is then manifested by the lower parts of the cloud gathering in on all sides towards the centre. (175.)

But if the Professor had made his figure to represent this view of the subject, *the wit would have disappeared.*

"All new theories," says the Professor, "from Symmes's down, explain some phenomena; and this imposes on persons not scientific. My theory, he says, does not explain all, and therefore is not the true one. For example—tornadoes sometimes commence in the night, when the air is cooled by contact with the surface of the earth, and therefore can have no tendency to ascend in columns, but rather to lie still from its superior weight. And even in the day, there can be no particular patches, on the surface of the earth, and especially on the surface of the sea, so much heated above surrounding regions, as to give rise to these upmoving columns of such tremendous power."

These objections have some plausibility, but it is a plausibility arising entirely from a misconception of the doctrine which I teach. In the first place, it does not follow, that because tornadoes sometimes occur in the night, the clouds themselves which formed these tornadoes, *commenced* forming in the night. These clouds might have formed many hours before they assumed the tornado character, and at a great distance from where they were first observed. And indeed if my doctrine is true, it must have been so; for it requires considerable time to form a cloud of such great perpendicular height as to make a tornado cloud, and during all this time, the cloud has a motion of translation.

It is manifest that when cloud is once formed, and comes over a region where the air at the surface of the earth is colder than that just above it, as it will be in the night, still from the great levity of the cloud, when compared with the air around the cloud, the whole column of air, even down to the surface of the earth will be forced upwards, by the superior weight of the surrounding air; and if there is but little difference between the temperature of the air and the dew point, when the cloud comes over a place, as it passes along over the surface of the earth even in the night, the air under it, being relieved from some of the pressure which was on it before the arrival of the cloud, will expand, and by the cold of expansion, condense a portion of its vapor into cloud, and thus the cloud will reach the earth.

Moreover there is a tendency in one tornado to form another, and the second has a tendency to form a third, and so on till there is a forest of them all in operation at the same time; and the annulus of each tornado will keep them apart for a short time. For as the barometer stands above the mean all round the tornado or water spout, in an annulus, in consequence of the rapid efflux of the air above in all directions from the centre of the cloud, the air at some short distance beyond the annulus will move gently outwards, at the surface of the earth from the tornado. This outward motion will have a tendency to form a new upmoving column on the windward side of the tornado, by its causing a resistance to the regular current of the air, and even on the leeward, it has the same tendency, by protruding the air faster in that direction than the common current of air is moving on that day. This will appear to any one who shall think on the subject carefully without any further elucidation from me. On the other hand, the more any one thinks of tops spinning round in the air, as the Professor said he conceived these spouts do, the less analogy will he see between them and this forest of water spouts, as the Professor called them, for the tops would immediately fly all to pieces, and cease whirling, if the cohesion of their particles should be destroyed, and so it would be with the air, even if it should be put into a whirling motion by some unknown cause, as its particles have no cohesion.

If, indeed, it should *commence* whirling without a cause —and no cause has ever been adduced for it—it might, for aught I know, *continue* to whirl without a cause.

My theory does not necessarily imply, that there are "particular patches" either on land or sea, warmer than elsewhere, which are *necessary* to the origin of upmoving columns—on the contrary, if the air at the surface of the earth or sea for thousands of miles around, should become heated, more than the air just above, or should become more highly charged with vapor, it would in either case form an unstable equilibrium, and it would be as philosophical to suppose that a needle nicely balanced on its point, would remain so forever in an agitated atmosphere, without falling, as to suppose upmoving columns of air would not be formed in this case. If a wave in the ocean, for instance, should be an inch high, it would destroy the equilibrium, and a current of heated air would start upwards from its summit and other heated air, or air highly charged with vapor would rush in towards the base of the ascending column, and the action would be continued and increased.

The Professor gives one more example where he says my theory fails to explain the phenomenon; that is, " why it does not rain in Egypt." And in this instance he says, " I adduce one hypothesis to explain another, contrary to the admitted laws of inductive philosophy."

To this I answer, that even if the phenomenon in question is not yet explained by my theory, yet, if it is not contrary to my theory, and impossible, if my theory is true, then may the theory still be true. But I do not concede so much. I contend that my theory explains the phenomenon, without an hypothesis. It is not an hypothesis that great rains are constantly falling on the mountains of Abyssinia during the whole time that the wind blows from the Mediterranean, across Egypt towards those mountains. It is not an hypothesis that the upper current of the atmosphere over Egypt runs in the opposite direction from the mountains of Abyssinia towards the north. It is not an hypothesis that this upper current contains in it the immense quantity of caloric of elasticity given out by the great quantity of vapor condensed there. It is not an hypothesis that this air, if brought down to the surface of the earth in Egypt, would be about 40° warmer than the air at the surface. It is not an hypothesis that cold air will not rise in warm, or in air warmer than itself; therefore, if thousands of upmoving columns of air should ascend every day over Egypt, as I suppose they do, they would not penetrate far into the upper current of air, because that air would be hotter than themselves. Besides, as these two currents move in different directions, the upmoving columns would be cut in two, and the lower part carried to the south, and the upper to the north; and in such cases, if my theory is true, rain could seldom be formed. If the wind blows from the south, then it will have parted with its moisture in crossing the mountains of Abyssinia, just as the air parts with all its moisture in crossing the Andes, before it reaches Peru. And if the air blows from the east or west over Egypt, it is not probable it would have much vapor in it, having passed over dry sands.

After all, if this explanation is unsatisfactory, and even incorrect, it does not invalidate the truth of my theory. It was some considerable time before the theory of gravitation, simple and beautiful as it is, could be reconciled to the lunar anomalies; but now these anomalies furnish the most decisive proofs of its truth.

Again; the Professor said "he rejected my theory because another explained the phenomena better." Under this head an experiment was shown to prove that a whirling motion in the air would explain the phenomena of storms better than an inward and upward motion. A very shallow, broad vessel, with water in it, was made to revolve rapidly in a horizontal plain, to prove that if air so revolved, it would move downwards in the middle and upwards and outwards at the sides; which the Professor said explained the phenomena of storms and water-spouts better than my system.

In this experiment, it appeared to me, the Professor utterly failed to show that any one of the phenomena attending the water-spout could be accounted for. If, indeed, the air rushed outwards below all round this metoer and downwards in the middle, then would the experiment exhibited be analogous. But what did the diagram of the New Haven tornado, shown by the Professor, prove? Why, most certainly, that the air moved inwards on three quarters of a circle at least — at the two sides and in the rear. I understood the professor to say that the air went up on the sides and down in the middle of the tornado, and that his experiment proved it, provided there was a whirl in the air. Now, I think the experiment did not even prove *that;* for if the sides of the vessel had been taken away, the water, on being put into circular motion, would have moved outwards and not upwards at the sides. And, in the case of the water-spout, if it whirled, the air must have moved outwards and not upwards, *for the sides of the vessel were all removed in that meteor.* It would almost appear from this experiment, that the Professor was an advocate for my theory, and intended to ridicule the whirlwind theory in the most sarcastic manner; for there the Professor had his diagram to prove, by ocular demonstration, that the air did blow inwards at the sides and in the rear; and then he exhibited an experiment proving that if there was a whirl, the air would move *outwards on all sides.* That this was really the object of that experiment is highly probable from two considerations: first, the Professor, in the beginning of his lecture, avowed that he was not an advocate for Redfield's theory; and second, it is the only supposition which will free him from the absurdity of bringing forward an experiment to prove a theory which it absolutely disproved.

If, indeed, the experiment was brought forward to show that a rapid whirl would cause an outward motion of the air at the surface of the earth, a downward motion of the air in the middle, and an inward motion of the air above, and, of course, a fall of the barometer in the middle, it would have been successful; but, unfortunately, there were no such motions of the air proved by the phenomena exhibited in the New Haven tornado. The Professor acknowledged there was an inward motion of the air below at the sides, and I am unable to perceive why he did not acknowledge the same in front and rear, as the corn-stalks, according to his own showing, in the New Haven spout, all in the centre of the path, lay with their tops forwards; and many bodies, near the centre, were moved backwards first, and afterwards carried forwards, and some were found west of the place where they originally stood. And the Professor did not attempt to deny that, in other tornadoes, many trees near the centre of the path are thrown down backwards, and are found lying underneath those which are thrown down forwards.

If it is contended that there is both an inward and whirling motion, in tornadoes, then the experiment altogether fails to illustrate or confirm the assertion. But the Professor had a ball attached to a string, which passed through a hole in the centre of a horizontal plane; to this ball, laid on the plane, a rapid motion was given, and prevented from flying off the plane by holding the string below; and when the string was drawn down, the ball, in its motion round, approximated the centre with increased velocity; and "so it was said the air would do, if a whirling motion should be given to it," by some unknown cause, or rather have a whirling motion as an ultimate cause, it being impossible to assign any cause for the whirl, or even conceive of one.

But neither does this experiment prove what it was intended to prove; for it is manifest that the ball would neither have moved in a circle, nor in a spiral inwards, if it had not been attached to the string; and if the string had broken, the ball would have instantly flown off in a tangent. Now, the particles of air supposed to whirl in a tornado *had no string attached.* Besides, if it should even be granted that there was a spiral motion inwards, it would not account for the fall of the barometer for any considerable length of time, for the great accumulation of air which would be the result, would cause the barometer to rise above the mean in the centre of the spout, unless it is granted that there is a more rapid outward motion above, which can only be accounted for on my theory.

It is not a little remarkable, that the fall of the barometer is the only phenomenon which the Professor mentioned as being better accounted for by the supposition of a whirling motion than by my theory; in this there was a manifest failure, unless the air went out at the sides below, and down in the middle, and inwards above. But besides the positive evidence furnished by the Professor himself, that this is not the fact in tornadoes, it is certain that if the air came down in the centre, it would not only not form cloud, but it would dissolve any cloud which it might have contained in the upper regions, from which it is supposed to descend. The Professor knew that I had asserted, if air should descend from a height sufficiently great to be condensed into half the space by the increased pressure, it would, by the heat of condensation, then be 90° warmer, and be able to hold eight times as much vapor as it could before it began to descend. This was proved by experiment, and was not contradicted by the Professor. It may, then, very fairly be inferred, that he has abandoned the doctrine which he formerly taught, "that a sudden production of cold would follow, of course, from the descent of such large quantities of air from the regions of perpetual frost, as would be driven down by the meteors of the 13th of November, 1833, falling into our atmosphere with immense velocity," as he said they did. [Silliman's Jour., vol. 18, p. 160.]

The Professor accuses me of making hypotheses, and founding my explanations on them; he attempted to point out but one, and *that* is already answered. Let us see for a moment how the old theory stands in this respect. It first supposes that large quantities of cold air from northern latitudes can be brought to meet and mingle with large quantities of warm air from southern latitudes, without assigning any cause of this meeting and mingling — which is not only an hypothesis, but one, if granted, that would not explain the phenomena. It supposes that on mingling, a sufficient quantity of vapor would be condensed to produce such rains as occur in nature; that is, in the Catskill shower, for instance, more than twice as much vapor as the whole atmosphere over the region of the rain contained. Although, if the advocates of this theory were to calculate the quantity, they would find that not half an inch of rain would be produced, if the two halves of the atmosphere were mingled together, both saturated with vapor, one at the temperature of 80°, and the other at zero. It supposes, in the case of hail, that the hailstone commences its formation at a great height, with a small nucleus, and receives continual accessions of matter in descending, until it reaches the ground; at which time, in some well authenticated instances, it is a foot in circumference; and this is the Professor's own theory. [Silliman's Journal, vol. 18, page 11.]

Now this is not only an hypothesis, but contrary to the known laws of nature. For, to say nothing of the heat of the lower air, which would have a tendency to melt the stone in part as it descended, it is known that it would be all melted by the caloric of elasticity alone before it would condense upon itself one-seventh of its whole weight of vapor. This may easily be conceived and demonstrated, by holding a piece of ice in the steam which issues from an opening in a steam boiler; for it is known that steam contains the same quantity of caloric, at all temperatures. And even if the nucleus had been 57° below zero — the temperature of the interplanetary spaces[1] — it would not condense on itself one tenth of its own weight before it would be raised to the temperature of 32°, at which point a further accession of vapor would diminish its size. It supposes that the air in the region where clouds are formed, contains a sufficient quantity of vapor to form such clouds and rain as nature produces; whereas a knowledge of the dew point would teach its advocates that all the vapor which the air contains, above the region of perpetual con-

[1] According to Fourier — Pouillet, however, makes it much more.

gelation, even if it was saturated from that point to the top of the atmosphere, which it never is, would not make one inch and a half of rain if it were all condensed. Now, in moderately cold weather, one of two things is certain, either a very large portion of a storm cloud must be above the region of congelation, where there is but little vapor to condense, or if not, then is the perpendicular diameter of the cloud, from its base to its summit, so small that the stratum of air of that thickness, can furnish but a very minute quantity of vapor to form cloud.

It supposes that the air in a summer day, when thousands of cumuli form, mingles hot with cold, and forms clouds in the form of sugar loaves, with flat bases, all on the same level with intervening spaces, where there is no mingling, without assigning any reason why it should mingle in that shape with the bases on the same level, and their tops at different heights. It supposes that this mingling goes on, without saying whether it is done by air coming down from above, and mixing with air below, or whether currents meet in a thousand different directions on the same horizontal level, or how there can be so many "patches" of cold and warm air in the neighborhood of each other, or why they rush into each other's embraces without any imaginable cause.

If it is supposed that the cloud is formed by a current of cold air coming down "from the regions of perpetual frost," and mingling with the warm humid air below, if it produced cloud on this principle, it would not be likely to stop till it reached the surface of the earth; and the cloud would be hollow, for the internal parts of the descending current could not mingle with the surrounding air, and there would then be an outward motion of the air in all directions, at the surface of the earth, from the centre of the descending current, which is contrary to known facts. If the cloud is supposed to form by an ascending current mingling with cold air above, in this case too the cloud would be hollow, for only the external parts of the ascending current could mingle with the air through which it passed. And if different currents on the same horizontal plane are supposed to mingle, it is an hypothesis contrary to nature, to suppose they would be of such different temperatures as to produce those very dense clouds which we see formed, by hundreds, almost every day in the summer, when the air to the north of one cloud is as warm as the air to the south. When gentlemen make hypotheses they ought to be careful not to make them contrary to known laws of nature, and when made they ought to explain at least *some* of the phenomena for which they are deduced. The Professor concluded his strictures, by reading me a lecture on monomania, without, however, directly mentioning that term, acknowledging " there was magnanimity in the course I was pursuing, but warning me of the danger of letting my mind dwell too much on one subject, and expressing regret that I had provoked this discussion." He declared he "had no interest but his desire for truth, in demolishing his opponent's theory; nor could he indeed expect to do so to the satisfaction of that gentleman, for he knew he had now become so enthusiastic in the opinions he advocated, in opposition to nearly the whole world of science, that he was blind to all evidence, and deaf to all arguments."

These observations were made, and this persevering tenacity to the old theory manifested in the face of the following demonstration of its incompetence to explain the phenomena which had been published in the Journal of the Franklin Institute, in 1836. Let the candid reader judge who is " blind to evidence, and deaf to argument."

Here it may be worth while to turn aside for a moment, to examine the efficiency of the most plausible theory of rain that has ever been given to the world. I mean that of

Dr. Hutton. He supposes two currents of air of different temperatures, both nearly saturated with vapor, to be mingled together, and that a precipitation of course takes place, in accordance with the known fact that at their mean temperature all their vapor cannot be retained, and therefore the surplus will be precipitated. This theory is defective in two respects: first, it does not show how two currents of air could be mingled to any considerable extent; and second, it does not show by calculation, that rain, to any considerable amount, would be produced, even if large masses of air at very different temperatures should be mingled together, which it would be easy to show never can happen, especially in the torrid zone. It may fairly be presumed that no advocate of the Huttonian theory would suppose that more than five hundred feet of a stratum of cold air could be mingled with a stratum of warm air five hundred feet of perpendicular height. Now, it will be found by calculation, that if one of these strata is at 60°, and the other at 40°, and both saturated previous to their mixture, the whole amount of precipitation, provided they took the mean temperature of 50°, would be less than a grain and one half on each square inch of surface. But as the latent caloric evolved in the condensation of the vapor would not suffer the mean temperature of the two strata, when mixed, to be acquired, but some temperature above 50°, therefore a less quantity than that mentioned would be precipitated. Such a quantity, in most cases, would be entirely evaporated in passing down through the air below, and never reach the earth.

It was mentioned before, that 5.1 inches of rain fell in Wilmington, on the 29th of July, 1834, in two and a half hours; let us see whether such a rain could be produced at all, on the Huttonian principles, making the most extravagant allowance for the quantity of air mingled, and also for the difference of temperature of the two strata.

Let us suppose then, that one half of the atmosphere at 80° Fahr., should be mingled with the other half at zero, over the region round Wilmington, and that 5.1 inches of rain is the result. What will be the temperature of the mingled mass after the rain? The mean temperature is 40°, which would be the temperature after the mixture, if no latent caloric is given out in the condensation of vapor. But from the principles explained before, it will be found that as five inches of rain is $\frac{5}{400}$ of the whole atmosphere in weight, the latent caloric given out in the condensation of the vapor forming this rain, will be sufficient to heat the whole compound 59.7°, which being added to the mean temperature 40°, will make the temperature of the air after the rain 99.7°, almost 20° hotter than the hottest half of the atmosphere before the mixture.

This result, however unexpected, ought not to appear surprising. For if gentlemen will frame theories on loose principles, without once putting these principles to the test of calculation, and without even taking the least notice of the latent heat of vapor, or the specific heat of air, they ought not to be surprised that a little plain arithmetic should dissipate their empty visions, and "leave not a wreck behind."

Theorists will pardon me for this sweeping denunciation, when I now voluntarily come forward and plead guilty to the same charge; for I too framed an hypothesis to account for rain, and advanced it under the high sounding name of theory.

Having found that the Huttonian theory would not bear the test of calculation, I imagined there was but one other possible mode of condensing vapor, and that was, that the vapor, by its own elasticity in the lower parts of the atmosphere, thrust itself up into a cold stratum above, whenever such a one overlapped the one below, and was thus condensed into rain.

This hypothesis I thought was altogether reasonable, from the great discovery of Dalton and Gay-Lussac, that vapor in the atmosphere rests only on vapor, and thus forms an independent atmosphere, and is not supported in the least degree by the air. I imagined then, that vapor could rush with great velocity from air where the dew point was high, to air where the dew point was low. But when I discovered that some rains were so great as to be beyond the power of this theory too, I began to suspect the hypothesis itself, which induced me to put it to the following trial.

I united two glass retorts together by their necks, then having covered one with snow, I put ten drops of water into the other and placed it in a vessel of water at the temperature of 130°, and let it remain in that situation seven hours, the temperature of the room during the experiment being about 70°; not one drop was distilled over in all that time.

I then took the retorts apart, leaving open the neck of the one having the water in it; it has continued in the room, open now for thirty days, with a temperature of 70° night and day, and the dew point in the room never as high as 40°, the ten drops of water being now only slightly diminished.

This refutes the hypothesis of rapid permeation of air by vapor, and indeed, proves that vapor, like heat, when it passes up to the upper regions, must be carried by the air, and not thrust up by its own elasticity. But to return from this digression; if the Huttonian theory is unable to produce such a rain as that at Wilmington, what will it do with the one which occurred at Genoa, on the 25th of October, 1822, when it rained thirty inches in twenty-four hours; or the one at Joyeuse, on the 9th of October, 1827, when it rained thirty-one inches in twenty-two hours?[1]

Or how will it account for a storm of hail[2] which fell in Orkney, on the 24th of July, 1818, in the afternoon, nine

[1] Pouillet, Elements de Physique, II, 758. [2] Edinburgh Trans. 1823.

inches deep in less than nine minutes? And here it may be remarked, that this is the storm mentioned before, in which the barometer was observed to fall nearly two inches, near the end of the storm, when it was not nearly so violent as it was in other places. Or how will it account for the immense quantity of rain which fell at Catskill, New York, on the 26th of July, 1819?

About half past five, P. M., a dense black cloud rose up from the south west, accompanied with a fresh wind, and about the same time, or a little after, a very thick dark cloud rose up rapidly from the north east. They met immediately over the town; at this instant a powerful rain commenced.

As soon as the clouds met, they seemed to fall down on the river, over which they met, and then the cloud rested on the water in such a manner that no space could be seen between them. For half an hour there was no appearance of drops of rain, the water appeared to descend in large streams and sheets. In this half hour the quantity fallen was above twelve inches on a level. Two persons testify that some time after the clouds met, they saw at the same moment a water-spout rising up from the river, nearly opposite, with a broad bottom, ascending to the clouds with a whirling motion, in the form of a pretty regular cone.

The whole quantity which fell was more than fifteen inches, over a space of about eighty square miles; and as far as I can collect from the whole account, which is given at large in Silliman's Journal, vol. 4, p. 124, this spout was stationary.

The intelligent author of the account, Benjamin W. Dwight, says, it is worthy of remark that eleven days before, in the afternoon, there fell, in a shower of short continuance, more than six inches of rain.

This theory has lately been brought forward and extended by Professor Olmsted, of Yale College, with a view of accounting more particularly for hail, than the original author of the theory had done. And though I am aware that the strength of my theory does not depend on the weakness of any other, I think it proper to give the Professor's remarks a passing notice.

"We assign," says Mr. Olmsted, "as the cause of hail storms, the congelation of watery vapor of a body of warm and humid air, by its suddenly mixing with an exceedingly cold wind, in the higher regions of the atmosphere. Let us examine," says he, "the effects which would result from the meeting of two opposite winds, at the height of 10,000 feet, during the heat of summer, the one blowing from the latitude of 30°, or from the confines of the torrid zone, and the other from the latitude of 50°, or the northern part of British America. If they had equal velocities, they would meet at the parallel of 40°; and, as in the case of the Gulf stream, a fluid does not readily change its temperature, merely by flowing through a body of the same fluid of a different temperature, and especially air through air, each current would retain nearly its original temperature.

"The southerly wind, blowing from a point which is still 2000 feet below the line of perpetual congelation, is comparatively warm, while the northern, coming from a point 4000 feet above the same boundary of the empire of frost, will have a degree of cold probably surpassing any with which we are acquainted. We infer from our preliminary principles, that immediately on meeting, the watery vapor of the warmer would be frozen with an intensity corresponding to the temperature of the colder current; that the minute hail stones thus formed and endued with such excessive cold, would begin to descend, and accumulate to a size proportionate to the intensity of the cold of the nucleus, and to the space through which they descended, and to the humidity of the lower strata of the atmosphere; that is, the colder they were when they began to fall, the farther they fell, and the more humid the air, the larger they would become."

As Professor Olmsted has not shown how these currents could be generated, the theory is plainly incomplete on this ground. And besides, even if they should be generated, it does not appear how they could be mixed; for either they would meet each other in opposite directions, and so stop each other's motion without mixing to any great extent, or they would slip by one another, without much affecting each other's temperature, according to the Professor's own reasoning.

But even, if it could be shown that a mixture of two currents could take place suddenly, of even 1000 feet in perpendicular extent, it would be very easy to show that under much more favorable circumstances, the dew point being higher, a grain and a half of rain to the square inch would not be precipitated, and that, in most cases, not a particle of this would reach the ground, for it would be evaporated in its descent, unless the air below should happen to be absolutely saturated with vapor, which seldom occurs.

But, according to Mr. Olmsted, " the minute hail stones being endued with a cold probably surpassing any with which we are acquainted, would begin to descend and accumulate to a size proportioned to the intensity of the cold of the original nucleus."

This remark is erroneous in two respects. First, the cold is certainly not more intense at this great elevation, than one degree for every one hundred yards, and is, therefore, in the northern current only $13\frac{1}{3}°$ below the freezing point; for, by supposition, it was only 1333 yards above the line of perpetual congelation, when it left latitude 50°.

Second; the original nucleus would not accumulate in the manner described; but, on the contrary, it would be entirely melted by the time it had descended far enough into the air below the line of perpetual congelation, to have condensed vapor less than one seventh of its weight. This will easily be perceived by comparing the relative latent heats of vapor and of water, and this, too, even if it received no heat from the warm air into which it fell. But even if the original nucleus were of the temperature of the interplanetary spaces, 57° or 58° below zero, it would not increase one fifth in size by condensing on itself the vapor, before it would be entirely melted by the disengaged latent caloric.

Professor Olmsted concludes his essay by saying that the momentum of a hail stone would be one hundred times greater if it did not, at every stage of its progress down to the very ground, receive new accessions of watery vapor, which, being matter at rest, is to be put in motion by the falling body, and consequently its speed is continally retarded. But he must now perceive, from what has already been said, that the velocity of descent will not be diminished one fifth, even when the stone has condensed upon itself vapor enough to melt it.

Before I take leave of this extension of Hutton's theory, I must notice another remark of Professor Olmsted, which, if correct, would of itself prove fatal to the theory which I have advanced. He says: "We have certain evidence from *the concourse of opposite winds*, and from the density and consequent blackness of the clouds, that a great condensation takes place in the region of the storm." Now, it appears to me that it would be much easier to account for the concourse of winds, by supposing a rarefaction in the region of the storm, just as a rarefaction in a chimney is the cause of the air in the room moving towards the fireplace. This, to my mind, is an elementary principle; and no authority, however great, could have the least influence in changing my view of it. From the following extracts, however, it would appear that Professor Olmsted has the authority of Marshall Hall and Mr. Varley in his favor on this point. Mr. Hall says: "The transition of atmospheric moisture from the elastic to the fluid state, must be attended by a diminution of bulk and elasticity, and consequently by a movement in the adjacent regions of the atmosphere and by a fall of the barometer." [Jour. Science and the Arts, vol. xx., p. 20.]

Mr. Varley endeavors to show, in correspondence with what he frequently sees, that storms of lightning will always occasion a current of wind from the external regions towards itself. Hence a dead calm preceding a storm, and a fall of the barometer, as this is the focus of condensation. [Vol. xxxiv. p. 162, of Tilloch's Mag.]

In conclusion, it is not a little remarkable that, in advocating the whirlwind character of the tornado, the Professor took no notice of a "test," laid down by Mr. Redfield, in the following words:

"If the traces or prostrations in the paths of tornadoes be the effects of a wind blowing from all sides directly towards the centre of the tornado, then the predominant effects of the wind *in the centre of its path*, will be found *parallel* to its course; but if the effects here, be transverse to the line of progress, then the prostration was occasioned by a whirlwind; no matter in which of the transverse, or longitudinal directions, the effects may have been produced."

This test I had accepted as a true one; and Professor Olmsted had already published to the world, that "near the centre of the New Haven tornado, the direction of prostrate bodies is coincident with that of the storm." If Professor Olmsted is "blind to evidence" furnished by himself, which Mr. Redfield says would satisfy him of the truth of my theory, then must I despair of ever making him a convert to my theory. *I appeal to the unprejudiced.*

Objections by Mr. Graham Hutchison, of Glasgow, with Replies.

202. DEAR SIR,—Last winter, I carefully read all the papers regarding your meteorological opinions, which you transmitted me. As I did not take notes of the various statements contained in them, I now put down the following remarks merely from recollection.

According to your theory, rain, hail, snow, water-spouts, land-spouts, cross currents of air, and barometric fluctuations, are all occasioned by one and the same cause, namely, upward vortices of air, produced and maintained by the same means, namely, heat evolved during the condensation of invisible vapor into clouds. And so far as I can ascertain from the documents transmitted me, you conceive that all these meteorological phenomena are never produced in any other way. Your theory is both simple and ingenious; but I find great difficulty in conceiving how the various meteorological phenomena presented to observation in this, and in other countries, can be reconciled therewith, or explained thereby. I shall state what appear to me to be imperfections in your theory, and objections that may be urged against it, just as they suggest themselves.

1st. I find no account given in your theory how the condensation of invisible vapor into cloud, which gives out the heat that occasions the upward aerial vortex, commences. And admitting, for the sake of argument, that rain is always, and only, occasioned by an upward aerial vortex, which, according to your theory, so far as I understand it, possesses the principle of self-perpetuation, I find no explanation given of how the upward vortex, and the rain thereby occasioned, should ever cease, when once it has commenced. Let us consider these two points separately.

Rain never begins to descend till the clouds have acquired a considerable degree of density. But your theory gives no account of how invisible vapor begins originally to condense into visible vapor, or cloud. If you say that condensation of invisible vapor begins in consequence of an upward vortex of air, the query then is, what originates this upward vortex of air?[1] According to my notions on the subject, the formation of clouds is chiefly occasioned by whatever reduces the temperature of the atmosphere; and this may be produced in a variety of ways, such as, 1st. By the reduction in the temperature which takes place during the transitions from day to night, and from summer to winter.[2] 2d. By the transportation of air by means of aerial currents, from a warm towards a comparatively cold latitude or locality.[3] 3d. By the elevation of atmospheric currents in surmounting hills and elevated lands.[4] And also, as I hypothetically conceive, (though I am very doubtful of the truth of this hypothesis,) by the slow ascension of

[1] The up-moving column of air may take its rise either from acquiring more heat or more vapor than surrounding portions of the atmosphere; for it is known, that vapor is only five-eighths the specific gravity of air.

[2] This cannot be the cause; for we have in this climate at all seasons numerous instances of entirely clear nights succeeding days with many clouds. No phenomenon is more common than for clouds to begin to appear at eight or nine, A. M., and increase till the hottest part of the day, and then gradually disappear after sunset. And in Jamaica this occurs every day in the dry seasons, almost always producing rain in the interior of the island about one or two o'clock.

[3] If cloud is produced in the first way, it ought to be in contact with the ground; for it can only be chilled by contact. This undoubtedly sometimes occurs, and fog is the result. But I have constantly observed, that when a very warm, and even damp atmosphere begins to blow from the south, after a very cold spell of weather, when the ground and stones of our pavement are so cold as to condense upon them a portion of vapor from the air, none of those clouds called cumuli are ever formed; the reason I suppose to be, that no up-moving columns can then be formed. Neither is cloud formed by the change from summer to winter; for there is more rain in the spring than in the autumn.

[4] This is undoubtedly one cause of clouds; but unless the cloud is specifically lighter than the surrounding air, how are these currents surmounting hills produced?

the atmosphere in the warmest latitudes of the earth, during the rainy season, in order to supply upper currents then diverging from these latitudes towards the north and south.[1]

These causes are assisted, 1st. By the gradual intermixture of different strata of air when the upper strata become colder and superficially heavier than those underneath, after making the necessary allowance for the reduction of temperature, and diminution in the specific gravity of the aerial strata, which results on ascending from the diminishing incumbent pressure.[2] And it does not matter, whether

[1] If this was the case, the whole torrid zone would be covered with eternal cloud.

[2] If cold air comes down from a height sufficient to double its density at the surface of the earth, its temperature would be increased about ninety degrees, and it would be capable of containing about eight times as much vapor as it contained before it commenced its descent, even if it had been saturated; and the more it mingled with air in descending, the drier it would make it—all which is known by experiment. And if heated air goes up, it is also known by experiment that it will condense more than one half its vapor by the cold due to diminished pressure, before it reaches sixty hundred yards high; and that too without mingling with the air on the outside of the ascending column. It is also known by experiment, that the vapor thus condensed, if the dew point is at 70° Fahr. (about a mean in our summer at Philadelphia), would give out as much caloric of elasticity into the air, where the cloud was formed, as would be given out by burning upwards of twelve thousand tons of anthracite coal on each square mile over which the cloud extends. And this would expand the air between six and seven thousand cubic feet for every cubic foot of water generated in the cloud, after making the allowance for the diminished volume due to the condensation of the vapor itself. There fell in twenty-two hours, at Ardêche, in France, thirty-one inches of rain, and it may easily be calculated that the caloric of elasticity given out during this time was sufficient to heat the whole atmosphere over the region where the rain fell to the above depth, 280° Fahr., provided no allowance is made for increased specific caloric of the air at great heights. The explanation of this astonishing phenomenon is too plain, according to my doctrine, to need any elucidation, except the simple statement, that a cold of about 90° is generated in every portion of air which rises high enough to become of half the density which it had at the surface of the earth. Nor is it difficult to find a sufficient amount of vapor to produce the amazing quantity of rain, which fell over the very limited region at Ardêche; for though the whole atmosphere, over the space where the rain fell, did not contain at any

the superior warmth of the inferior strata be occasioned by clouds arresting the radiant heat passing downwards towards the surface of the ground during day, or passing upwards from that surface during night; or whether it be occasioned by the evolution of heat which attends the condensation of invisible vapor into clouds during the transportation of air from a warm to a comparatively cold locality, or any other cause.

The causes before mentioned are also assisted, 2d. By the more rapid diminution of the elasticity of aqueous vapor than that of air, as the temperature of both is reduced in ascending perpendicularly. This is unquestionably the chief cause of clouds forming at a considerable altitude in the atmosphere, rather than nearer the level of the sea. Indeed when the ocean to the north is warmer during the depth of winter than the incumbent atmosphere, and much warmer than the land, evaporation may, and frequently does, go on from the ocean to such an extent as to produce long continued rainy and cloudy weather, when the wind blows from a northerly and cold direction. Our snow storms from the north east or north west, and I apprehend your snow storms from the north east, during the coldest season of the year, are produced in this manner. The moisture evaporated from the then warm surface of the ocean is condensed into clouds as it rises in the cold atmosphere. And this condensation is promoted by the farther reduction of temperature which it undergoes, in being transported over the cold winter surface of the land by aerial currents. In the climate in which I reside, the principal cause of the formation of clouds undoubtedly is, the transportation of air from a warm towards a comparatively cold locality by means of aerial currents. But whatever causes clouds to

one time one fourth as much vapor as would be required to make thirty-one inches of rain, yet the great ocean of vapor surrounding the region in question, by flowing in, and ascending with the up-moving current of air, might easily furnish a supply to any amount.

begin to form, if continued, must increase their density until rain is produced.

Again, if clouds and rain be produced only by an upward vortex of air, (supplied by converging currents below the clouds, and disposed of by diverging currents above them,) which, according to your theory, has the power of perpetuating itself; when once begun, it should become a sort of perpetual motion, that could not by any possibility come to an end. But instead of this being the case, we find that all rains terminate.[1]

2d. If you state that upward vortices must be occasioned during day, by the atmosphere nearest the surface of the ground becoming then much more heated than the aerial strata above, the following and similar objections present themselves: 1st. How does more rain fall during night than during day? 2d. How does it never rain in Egypt, where the wind blows almost incessantly from the north, that is, from a cold towards a comparatively warm climate, and from the sea towards the land? According to your theory, the cold saturated air from the Mediterranean should have

[1] When a lofty cloud is once formed, it certainly has a self-continuing power; and accordingly, we find that many storms originating in the West Indies, have continued for many days and nights in succession, and travelled many thousand miles from the place of beginning; terminating, it is true, in one place, but continuing to rage with violence in another. But to infer that they could not, by any possibility, come to an end, if they are really generated in this way, is illogical; for there may be many causes tending to diminish and finally destroy their force.

The quantity of rain which comes down from a great height has a tendency, both by impulse and its cooling effect on the air below, to diminish and sometimes stop its upward motion, and in the case of the rains in Jamaica, in the middle of the day, they appear to invert the motion, and produce a land breeze towards evening. And when the land breeze commences, the air over the middle of the island must come downwards, and then not only will the rain cease, but the cloud which was formed by the upward motion will disappear, as it comes under greater pressure — as is demonstrated by experiment. Other means of terminating storms were explained at the latter end of the section on meteoric rivers.

an unusual tendency to rise in vortices as it became heated in passing over the heated sands of Egypt; and contrary to what is the fact, should there produce incessant rain.[1] 3d. In like manner, how does it happen that at Marseilles, during the depth of winter, when the wind shifts from the north, and begins to blow from the south, that is, blows from the Mediterranean, and from a warm towards a com-

[1] This objection seems to be founded on an illogical deduction from my doctrine, that because all rains and snows and hails are produced by an up-moving current of air, therefore all up-moving currents of air must produce rains, hails, or snows. This does not follow: for if any one will take the trouble to look how cumuli are formed in a summer day, he will see them sometimes swelling up to a great height, and then, not yet having got dense enough to rain, their tops will be swept off by an upper current, moving in a different direction from themselves, or with a different velocity; and they will thus become spread out along the heavens, and their up-moving power destroyed. Now, when the north wind blows in Egypt, the current below is almost diametrically opposite to what is known to be the direction of the current above in that latitude.

Besides, the current above contains all the caloric of elasticity which was given out to it, during the great condensation of the vapor which produces the mighty rains as it passes over the mountains in Abyssinia: so that it will contain very much more caloric to the pound than even the hot air on the surface of the ground in Egypt; and, therefore, when the up-moving currents over that country rise to the height of this upper current which is flowing off towards the north, they will enter a medium of less specific gravity than themselves, and on that account they will cease to rise.

Besides, I have long observed that if the dew point is more than 20° below the temperature of the air, cumuli hardly form, though the day is entirely clear, and up-moving columns forming as usual. This circumstance is easily understood, when it is known, as it is by experiment, that these columns cool about one degree and a third for every hundred yards that they ascend, whilst the strata of the atmosphere itself are only one degree colder for every hundred yards high. From these two facts it follows, that though the columns start upwards by their specific levity from greater heat near the ground, they are constantly, in their ascent, approximating nearer and nearer to a state of equilibrium with the surrounding air at their own elevation, and finally must cease to rise, unless they reach the point where cloud begins to form, and then as the law of cooling is changed to about two degrees for three hundred yards, the upward motion will be continued, unless hindered by some of the causes mentioned above.

paratively cold land surface, clouds should rapidly begin to form and increase in density till rain begins to fall? The surface of the land being then so much colder than the incumbent atmosphere brought by a southerly wind from the Mediterranean, cannot give rise to an upward vortex upon any principle that I can conceive; but, on the contrary, by communicating its coldness to the incumbent atmosphere, and thereby increasing its specific gravity, should rather counteract any tendency to an upward vortex of air.[1] In like manner, in the United States of America, where you reside, when the wind, during the depth of winter, blows from an easterly direction, that is, from the Atlantic, and a then warmer climate, clouds begin rapidly to form and rain follows, in consequence of the reduction of temperature which the comparatively warm atmosphere from the Atlantic undergoes in being transported over the then cold

[1] The effect here, I think, is put for the cause, and if so, the whole difficulty vanishes. The blowing of the south wind at Marseilles is not the cause of the formation of cloud, but the formation of cloud and the commencement of the south wind are simultaneous effects of the same cause. Now this south wind will bring with it a high dew point, and, of course, a light air, well calculated to run in under the base of a cloud already formed, and from the high *steam power* which it contains, calculated to increase its power of upward motion.

It is asserted that clouds begin to form after the south wind begins to blow: but if it should be discovered hereafter that the clouds begin to form at the same time, the whole phenomenon is explained, and another strong link is added to the chain of evidence which is already formed in favor of the *law of storms* for which I contend. Now I have known many instances of long continued rains in the north, while there was a constant south wind, or rather west of south, in consequence of oblique forces operating generally to produce that effect in this latitude; and I never yet heard of a great rain in the western part of New York, without a southern wind at Philadelphia. And it will be very readily seen, that any air, however cold, if it is near the borders of a lofty cloud, will run in under that cloud, and be forced to ascend, when it comes under it, if a cloud has indeed the specific gravity which I assign to it: so that although a warm south wind blowing over a cold surface of land may be unsuited to originate an upward motion of air, yet it is well calculated to continue that upward motion after it is originated.

surface of the land.[1] But no upward vortices of air could be thereby generated, so as to account for the formation of clouds and rain agreeably to your theory. On the contrary, during the depth of winter, from Christmas till the end of February, when the prevalent wind in the United States is from the west or north west, that is, from a cold towards a comparatively warm climate, upward vortices of air, and clouds, and rain, agreeably to your theory, ought to be produced; whereas, clear, dry, frosty weather is then the invariable concomitant of such a wind. Similar observations are applicable to the climate in which I reside, and in all others in temperate and cold latitudes. The most rainy winds are those which blow from a warm towards a comparatively cold climate; and the driest winds are those which blow from a cold towards a comparatively warm climate. But the former, viz. the rainy winds, can never originate an ascension of the undermost atmospheric strata; whereas, the latter, upon the principle of monsoons, and sea and land breezes, must always produce that tendency in a greater or less degree.

3d. In certain great rains, mentioned in your reports, ex-

[1] The whole doctrine of our north east storms appears to be entirely misunderstood. During their entire progress from the West Indies, in which they frequently originate, to Maine, the wind does not blow from a warmer to a colder climate, but the reverse. When the storm is yet in the West Indies, the wind is blowing from the north; and when it reaches South Carolina, the wind in North Carolina and Virginia is from the north east, and when it reaches Virginia, it is blowing in Pennsylvania and New York and Massachusetts, from the north east, and in Ohio, from the north west; and in the northern borders of the storm, the wind is most violent from the north, and the quantity of snow is the greatest, as far as ascertained. (116, *et passim.*) Moreover, whenever these storms pass Philadelphia, and are raging in the north eastern states, the wind invariably changes to some western point, sometimes to the north of west, and sometimes to the south of west. It is true, that on the southern borders of these storms, the wind, at the same time, is blowing from some southern direction, and no doubt contributes much to the violence of the storm, from the quantity of steam it brings to the focus of action.

tending simultaneously over a surface of many hundred miles in diameter, the wind at the surface of the earth, over the whole extensive tract of country where the rain fell, is said to have been blowing with great, or considerable, force, towards the centre of where the rain was falling; that there it fell in greatest quantity; and there, and there only, so far as I understood your report, the upward vortex of air existed. Now I am at a loss to know how any rain should have fallen, agreeably to your theory, beyond the boundaries of your supposed upward vortex of air. If clouds and rain are produced only by an upward vortex of air, how did it happen, on these occasions, to rain simultaneously for several hundred miles east, west, north and south, of the supposed upward vortex?[1]

4th. If your theory supposes that an upward vortex of air exists over the whole extent of surface where clouds are forming, or rain falling, the clouds, when viewed from the surface of the ground underneath, should always be stationary, though the wind be blowing underneath with great velocity, and in one determinate direction. Now in this country, (and I suppose it must also be the case in America,) when the wind blows with great or considerable velocity in one determinate direction, and clouds are forming or rain falling, the clouds are always moving in the same

[1] Here again the doctrine taught by me appears to have been entirely misunderstood or overlooked.

The doctrine I have taught in all my essays is, that as soon as the air around a cloud comes in under its base, it is under less pressure, and begins to ascend, not, of course, perpendicularly, but obliquely. It is only in the centre where the motion can be perpendicular; and so far from the greatest quantity of rain falling always in the centre of the storm, it sometimes happens that the perpendicular velocity of the air is so great, that the drops of rain are not permitted to fall there, but are carried up to a great height, and then spread outwards towards the borders of the storm, and fall there, where the upward motion is not sufficient to overcome gravity, and even beyond the borders of the upmoving current where the barometer stands above the mean.

direction, and, as nearly as can be estimated, with the same velocity as the air near the surface of the ground. Indeed, I have never, in a single instance, observed clouds remaining stationary during a very heavy rain, when the wind underneath was blowing strongly. Besides, the edges of clouds are frequently of such a ragged and marked character, and retain the same distinctive configuration for such a length of time, that if there was any rapid upward vortex of air underneath, such as is stated to be the case in your reports, the upward movement of the edges of the cloud would have been long since observed, and universally admitted; whereas, though horizontal movements of clouds during rain are constantly observed when there is any wind, an upward movement from underneath never has been noticed, and is not visible, so far as I am aware.[1]

[1] In our great north east storms, when they approach Philadelphia from the south west, within three or four hundred miles, the wind begins to blow from the north east, and at the same time the top of the cloud from the storm generally makes its appearance, coming from the south west; and those two currents in opposite directions, continue for several hours before many clouds form below — and even when they do begin to form below, by the gradual sloping of the air upwards, the upper clouds are still seen through the openings, coming and thickening from the south west.

It is true, indeed, when the storm of rain or snow comes on, the upper clouds are concealed entirely from view, and the lower clouds, being in the under current, are seen moving in the same direction with the wind.

Moreover, in violent summer thunder showers, which are sometimes only ten or twelve miles wide, I have frequently seen the clouds in the lower part move with great rapidity towards the centre of the cloud from all sides, and before I knew of the upward motion of the air in the middle, I have stood looking on with amazement, at not seeing them overlap, but seem to lose themselves in the centre, and others succeed in their turn. But when I calculated the effect produced by the evolution of the caloric of elasticity which is given out during the formation of cloud, and found that the volume of air in which the cloud was formed would be increased about six times as much by receiving this caloric, as it would be diminished by the condensation of the vapor into water, the mystery was immediately explained. And I think the reader will find, that this single principle, in connexion with other laws, previously well known, will leave but few mysteries in meteorology, except the luminous meteors, unexplained.

5th. If I recollect right, you mention in one of your reports, that the heat communicated to the incumbent atmosphere by some very limited combustion underneath, gave rise to an upward aerial vortex which occasioned a local thunder storm, accompanied with heavy rain. I am inclined to think that if such a limited cause of increased aerial temperature produced the thunder storm in the case referred to, there would be an almost constant upward aerial vortex, accompanied with thunder and rain, over every large city. London, including its suburbs, extends about twelve miles in length, by eight in breadth, and contains a population of about 1,800,000. In calm weather, particularly during winter, the increase of temperature communicated to the atmosphere by the combustion of fuel and animal respiration over the central portions of such a large city, cannot be less than eight or ten degrees beyond that of the atmosphere in the surrounding country. But instead of an excess of rain falling over London, the annual amount of rain there is only 22.2 inches, which is less than in almost any other part of England, where observations have been made. The air in the central parts of Glasgow during calm weather, in winter, is usually six or eight degrees warmer than in the surrounding country. Now, if this excess of atmospheric temperature occasioned an upward aerial vortex so as to produce clouds and rain, as should be the case if your theory were correct, the amount of rain that falls at Glasgow should be unusually great. But instead of this being the case, the annual amount of rain collected in the rain gauge kept at the M'Farlane Observatory, College Garden, when averaged for upwards of thirty years, was only about 22 inches; whereas the annual amount of rain collected in every one of the rain gauges kept within a limited number of miles of the city, was considerably greater. The circumstance of the amount of rain collected in the rain gauge kept at the M'Farlane Observatory being so much smaller every year than what was collected in any other rain gauge in the surrounding neighborhood, attracted so much attention, that a committee of skilful mechanics and mathematicians were appointed to examine it. And they, after minute examination, reported that its construction and condition was in every respect accurate and perfect.[1]

6th. In one passage of the documents sent me, clouds, so far as I recollect, are stated to have been observed eleven miles high; and in another passage, fourteen miles high. No observations ever made in Europe, that I am aware of, have afforded evidence that clouds, even of the cirous kind, exist in the atmosphere above the elevation of 25,000, or 30,000 feet, at most.[2]

7th. According to your theory, barometric fluctuations

[1] I do not recollect that I ever said, in any of my writings, that the heat communicated to the incumbent atmosphere by a very limited combustion, occasioned, by the upward motion produced in the air, a local thunder storm, accompanied with heavy rain. But as it is my belief that great fires under favorable circumstances, may produce rains, I may have said something like it. But as this is a mere matter of opinion, and as it can only be decided by experiment, which I hope soon to try, I forbear to dwell on this point. I am, however, grossly misinformed if it does not rain much more frequently in and about large manufacturing cities in Europe, especially in Great Britain, than in other parts. It does not follow, however, from this, that there will be more rain in the city itself than in the suburbs or the adjacent country; for the air is seldom so still, that the column of cloud which might be formed over the city by the upmoving column of air, would remain so perpendicularly over the place of its formation, as to rain down on the city itself, as much as it will in the suburbs and neighboring regions; and as the wind prevails from the west in the British isles, it is likely that more rain would fall on the east side of these great manufacturing towns than on the west. In accordance with this theoretical deduction, my friend, Mr. T. Sully, on his return from Europe, told me, that in comparing notes with Mr. Leslie, he found that Mr. Leslie had many more favorable days for painting in the west part of London, than Mr. Sully had, who was more eastern, on account of the thick weather and misty rain, which prevailed more where Mr. Sully lived. (More observations on this point are much wanted.)

[2] The steam power of the clouds in the United States is much greater than it is in Great Britain.

are occasioned exclusively by the same cause that produces clouds and rain, and which you say is an upward vortex of air, produced and maintained by heat evolved during the condensation of invisible vapor into clouds. Now when it is considered that the amount of rain which falls in a given time, and the amount of heat evolved during its conversion from invisible vapor into clouds, decreases from the equator to the poles, your hypothesis cannot be reconciled with the fact, that the range and fluctuations of the barometer, instead of decreasing, (as would be the case if your hypothesis were correct,) rapidly increases from the equator to about the 60th parallel of latitude, and again decreases from the 60th parallel as we advance towards higher latitudes. That this is the case, is evident from the following table :[1]

		Mean annual range of the barometer.
Quito,	S. lat. 0° 13	about 1 line.
Peru,		$\frac{1}{3}$ of an inch.
Calcutta,	N. lat. 22° 35	$\frac{1}{2}$ of an inch.
Kathmander,	lat. 27° 30	.85 an inch.
Capital of Japan,	lat. 32° 43	.85 an inch.
Paris,	lat. 48° 50	$1\frac{1}{4}$ inches.
Great Britain, averaged		2 inches.
Petersburg,	lat. 59° 56	$2\frac{1}{4}$ inches.
Melville Island,	lat. 74° 30	1.86 do.

[1] According to my theory, undoubtedly the great barometric fluctuations are produced solely by the caloric of elasticity evolved by the condensation of vapor in storms.

I have made the calculation how much the barometer ought to fall under a cloud of a given height, with a given dew point, that is, with a given steam power in the air, and as this calculation is made on acknowledged scientific principles, it must stand, unless the principles themselves fall. The objections leave this fundamental principle unimpeached. No notice has been taken of it.

It is true, indeed, that my "doctrine cannot be reconciled with the fact, that the range of the barometric fluctuations rapidly increases from the equator to about the 60th parallel of latitude." And if this were really a fact, There is no doubt that such a thing as upward vortices of air, and gradual ascensions of large tracts of atmosphere

it would be fatal to my doctrine, so far as the barometer is concerned, and then I would have to abandon the whole ground. But the fact is not so. If the reader will turn to Col. Reid's late work on hurricanes, he will find, at page 59, that the barometer fell at Porto Rico to 28 inches, on the passage of a hurricane, and rose 1.17 inches in an hour and a half. And at page 269, the barometer fell in the Bay of Bengal, in a tremendous hurricane, to 27.80 — having stood at 29.70 at the beginning of the storm. And at page 271, the mercury sunk out of sight below 26.50, having stood three hours before over 29 inches. This was at the mouth of the Hoogly — while at Calcutta, about one hundred miles off, the barometer fell only three quarters of an inch. (150, 151.)

Now, as these great fluctuations occur in these latitudes only when a great hurricane occurs, and are known to accompany the hurricane in its progress, and are great in proportion to the violence of the storm, and are confined to the region of the storm itself, and especially as it is now known that the barometer rises on the approach of the borders of a storm, it seems almost certain that the cause of the storm is the cause of the fluctuation, unless they are related to each other, as cause and effect. (170, Table.)

Indeed, if it is a fact, (and nothing is better established) that the barometer does stand low in the middle of these great hurricanes, all the other phenomena connected with them are mere corollaries. The wind will blow inwards with a velocity proportionate to the square root of the depression of the barometer; it will rise in the central parts of the storm in a similar ratio, that is, with the velocity of about 240 feet per second for a depression of one inch, without making any allowance for the rise of the barometer in an annulus all round the storm, in consequence of the rapid efflux of air on all sides in the upper part of the cloud; and even the very quantity of vapor condensed per second may be calculated, if the dew point and depression of the barometer are given; and it is found adequate to produce those mighty floods of rain which are known to fall in these storms. The quantity of rain which sometimes falls in one of these hurricanes, over a limited space, is certainly as much as ten inches; in which sufficient caloric of elasticity is given out to heat the whole of the air over this region, from the top of the cloud down to the surface of the earth, more than one hundred degrees. But when it is considered that every portion of air which rises from the surface of the earth to that height, undergoes a refrigerating process of more than one hundred degrees, from diminished pressure, and that it would actually become colder to that amount, if it were not for the caloric of elasticity given out in the condensation of the vapor, which prevents it from cooling more than about half this quantity, as I have demonstrated by experiment, it will no longer be a supplied from underneath, by aerial currents near the surface of the ground, are constantly and simultaneously occurring on an immense number of different parts of the earth's surface. Whirlwinds afford examples of upward vortices of small extent. Sea and land breezes, monsoons, and local as well as more extended winds, blowing from a cold towards a comparatively warm climate or locality, can only be accounted for by supposing that opposite aerial currents simultaneously exist in the upper and lower halves of the atmosphere. The air, in such circumstances, must be gradually descending over the cold locality to supply the lower current, and ascending over the warm locality to supply the upper current. But some of the facts which I have mentioned, such as the case of the north wind in Egypt, sea and land breezes in intertropical climates during the dry season, and the general fact of all winds that blow from a cold towards a warmer locality, being comparatively dry winds, show that the upward ascension of air is not the only cause of rain.[1] And judging from the facts mentioned,

mystery how so great a quantity of vapor is condensed by cold, in air which is at the same moment receiving such an immense amount of caloric.

[1] This conclusion does not follow from the premises. It would be logical to say, these facts show that an upward motion of the air is not always a cause of rain; and such is undoubtedly the fact. I have myself seen hundreds of upmoving columns forming large cumuli without producing rain; but it certainly does not follow from that fact, that cumuli are ever formed without upmoving columns.

Flat low islands in the West Indies have sea breezes, and of course upmoving columns in the central parts of them, but there being no mountains to prevent these columns from being swept off, out of the perpendicular, before they rise high enough to form dense and deep clouds, rain is frequently not the result. Now, when the wind blows from the north west at Philadelphia, though upmoving columns may be formed in great numbers, as they no doubt are, yet they do not rise very high till they enter a current above, moving in a different direction, and though clouds may begin to be formed before they enter that current, yet, when they do enter it, the columns will be broken and their force destroyed.

On the contrary, whenever the lower current of the air is moving in the and others of a similar kind, I am very doubtful if an upward vortex of air, either upon a limited or an extended scale, (except upon the principle of intermixture,[1] and also

same direction with the upper, and with the same velocity, which can only be the case in this latitude, when the wind is from some southern or south western direction, then the columns can rise to a great height without being broken, and this is one reason why a southerly wind is favorable for rain. These observations apply exclusively to the generation of a rain cloud, and not to the phenomena which occur after a great rain cloud is generated. After that is done, the cloud has a self-sustaining power, and frequently continues as violent in the night as in the day, and if even it should be found to discharge more rain in the night than in the day, as asserted above, it would not be inconsistent with my theory.

[1] The doctrine of the intermixture of airs at different temperatures producing rains, will not bear the test of examination. I demonstrated, in the very essays here criticised, as the reader will see in the Journal of the Franklin Institute for 1836, that if the two halves of the atmosphere, the upper and lower, one at the temperature of 80° and the other zero, both saturated with vapor, should be mingled together by magic, (for they cannot be mingled by any causes in nature,) that the caloric of elasticity given out in one of our great thunder storms, (5.1 inches of rain) if communicated to the mass of air so mingled, would leave the whole about 20° hotter than the hottest half before the mixture. But why suppose a mixture in case of an upward motion of air, as it is here supposed, if it goes up to where the barometer would stand fifteen inches, it would cool without mixture at least 85°, as I have demonstrated by experiment, if no allowance is made for the caloric of elasticity given out by the condensing vapor.

And if any one will carefully watch a cumulus cloud while forming into a nimbus, if he is properly situated for seeing the whole phenomena, he will observe a wonderful stillness in the borders of the cloud, while it is puffing out at the top, as if it were "blown into below by a pair of great bellows." (70.)

He will see the lower part of the cloud much agitated, and flocculi darting in from the borders towards the centre, and finally, small clumps of clouds suddenly forming some distance below the black base, and darting up into that base, " like sky rockets;" in short, the whole phenomena corresponding precisely with the supposition of an upward motion of the air, both below and above the base of the cloud. If this cloud is formed from the mixture of airs of different temperature, which I have shown could not be, on other grounds, I think it is certain that it could not assume the present form. If it were formed of strata of air, one over the other, and moving in different directions, so as to mingle between them and produce cloud, then the cloud would have a flat appearance, and could not possibly rise into a pyramid of six or eight miles in height, in a very short space of time, in regular form.

when the atmospheric current rises in surmounting hills,) is ever, in any instance, a cause of the formation of clouds, or of the descent of rain, *in temperate or cold latitudes.* And from comparing the extreme smallness of the fluctuations and range of the barometer in intertropical climates, where the rains are heaviest, with its great fluctuations and range in temperate latitudes, where the amount of rain is comparatively very small, it is obvious, that if clouds and rain be occasioned by upward vortices of air, barometric fluctuations must be either wholly occasioned, or at all events much assisted, by some other cause.

If it was formed either by an upmoving column of warm air, or by a down-moving column of cold air, mingling with the air through which it passed, then would the cloud appear something in the form of a hollow cylinder, for the central parts of the ascending or descending column could not mingle with the surrounding air. Now, the central parts of the cloud seem to be much the densest, if we can form any judgment from the blackness of the base, just as it should be on my principle, but not at all on the Huttonian. It will not surely be contended that air can be mingled to any extent sufficient to produce large clouds by different currents meeting each other on the same horizontal level, and even if it should, it could not be imagined how a cloud in the shape of a sugar loaf could be formed on this principle, with a flat base always just about as many hundred yards high as the temperature of the air is above the dew point in degrees of Fahr. at the time the cloud is forming, which exactly corresponds with the height of the base, on the supposition that the air does move up from the surface of the earth into the base of the cloud. Besides, if it should be found, as is highly probable, that the upper portions of the atmosphere always contain more caloric to the pound than the lower, from the caloric given out there by the vapor condensing into cloud, the doctrine of mixture forming a cloud, would have to be given up on this ground alone.

I have now attempted to answer all the objections which have been brought against my theory by a gentleman of highly cultivated and acute mind, one who has himself written one of the best treatises on meteorology extant, and also a very late work on Unexplained Phenomena, which I do not hesitate to say manifests great originality and power of thought, though I am not yet prepared to subscribe to all his views.

If I have not been entirely successful in answering, to the satisfaction of the candid reader, all the objections, I think it will be but fair to set down the failure, not to the weakness of the theory, but to the want of skill in the

The preceding remarks are penned in a spirit of perfect candor and impartiality, and I hope you will receive them in a similar spirit. They will point out the objections to

advocate. Indeed, I doubt not that the intelligent reader who has made himself thoroughly acquainted with the theory, will see that many points could be much more clearly elucidated. If, indeed, I had not been able to answer any one of the objections, the theory might still be true, for the foundation of it is not shaken by any one of them.

Suppose, for instance, I had not been able to show that the barometer does actually fall in the torrid zone, on the passage of a hurricane, it would not prove my theory untrue, because it might have so happened that no barometrical observations had ever been recorded in the midst of the storm. If, indeed, it had been established by well-authenticated observations, that the barometer does not fall in the middle of a hurricane, I would have to acknowledge it to be the *experimentum crusis* to disprove my theory. But this fact never will be established. For so long as the laws of gravity remain unchanged, the barometer will fall when pressed by less incumbent weight; and as long as the relation between the caloric of elasticity of vapor and the specific caloric of atmospheric air, remains unchanged, this caloric will expand the air in contact with the condensing vapor, in the formation of cloud, upwards of six thousand cubic feet for every cubic foot of water thus generated, after making allowance for the condensation of the vapor itself; as I have demonstrated by experiment, independent of the chemical principles on which the calculation was originally made. (65.)

I thank the author of these able strictures for the candid manner in which they were made. If my theory is true, it will bear the test of the severest examination, which I invoke from other minds of equal acuteness. If it is false, no one is more interested than myself that it should be speedily refuted. But in this inquiring age, when men will think for themselves, neither the hasty and unpremeditated opinion of one of the most distinguished philosophers of Europe, that Mr. Espy's theory could not be true, for it requires the barometer to stand high in the middle of hurricanes, nor the deliberate and long-cherished opinion of a distinguished chemist of America, of whose discoveries his country is justly proud, that Mr. Espy's theory is suicidal, requiring the air to be colder, to condense the vapor, and at the same time warmer, to produce an ascending motion, will satisfy the mind of any one who chooses to investigate the subject thoroughly; for he will perceive, that neither of these conclusions follows from the doctrine which I teach.

The foundation on which I build must be sapped, before the superstructure can be overthrown. Let any one try the following experiment, and he will be able to tell whether my corner-stone is firmly laid or not. Try how much the temperature of both dry air, and air saturated with aqueous vapor, is reyour theory which most readily suggest themselves to the mind of an impartial reader. If your theory be true, you will be thereby enabled to know what points require further elucidation, and also what objections ought to have been anticipated and answered,—an object which, in advancing a new theory that has to contend with preëxisting opinions, ought never to be lost sight of.

I am, dear sir, your most obedient servant,

GRAHAM HUTCHISON.

Glasgow, Scotland, 11th October, 1838.

Objections by Mr. Hopkins, of Manchester, England.

A converzatione was held on the 4th inst., at which the subject was, "Meteorological facts relating to the great storm of January, 1839," by Mr. Hopkins. In the discourse delivered by that gentleman, it was stated, that little was at present known respecting those local movements of the atmosphere which constitute our storms. Notwithstanding the advance that has been made in other branches of knowledge, and the high degree of interest that has always been felt by mankind in those sublime and often destructive phenomena of nature, our knowledge of the particular local causes which produce storms is not much greater than that possessed by man thousands of years ago. It is, indeed, only when storms do great damage, and thus excite public interest, that we can at all collect facts from a sufficient number of places, to enable us to take any general view of what has been going on in the atmosphere at the time.

duced in temperature by a given diminution of pressure, and if he finds, at ordinary summer temperatures, the moist air reduced only about one half that of dry air, as I have found it, he will, by careful examination, be able to perceive, that all the doctrines which I teach on this subject, follow as corollaries from this single fact, in connection with other facts heretofore established.

The narrations, however, generally consist of instances of destruction of property and life, and it is only incidentally that instructive meteorological facts are named. But such accounts are nearly all that we have to rely upon; and we have, therefore, only to make the best use we can of them. The great storm of January, 1839, to which attention would be more particularly drawn, was so exceedingly violent, and caused the destruction of so much property both on sea and land, and the loss of so great a number of lives, as to cause an unusual number of accounts respecting it to be published all over those parts of the country where it raged. It is, consequently, more worthy of attention than any other that has occurred in this part of the world for a long time past.

In the present state of our knowledge, it cannot be said there is any established or generally recognised theory of storms. It has, for a considerable time, been considered that they were connected with an intermixture of the general atmospheric currents; but in what way that intermixture was effected was not known. Recently, Mr. Redfield, in America, and Colonel Reid, in this country, have attempted to show, that all great storms are whirlwinds, and they give facts to support their theory; but they do not attempt to show how the storms originate. Mr. Espy, of Philadelphia, lately explained in this room, and still more recently at the meeting of the British Association at Glasgow, a new theory which he has advanced. This theory is, that, from certain causes, which he explained, the lower part of the atmosphere, in particular places, moves upwards, leaving an approach to a vacuum in those places, which causes the adjoining lower portions of the atmosphere to rush in from all around, thus forming converging streams rushing towards a centre. These streams (as he represents), when they arrive at the central space, rush upwards; and this process continues while the storm lasts. Mr. Espy exhibited a map of the British Islands, marked with arrows, to show the direction of the wind at the time of the storm of January; and he maintained that the phenomena attending that storm harmonized with, and confirmed the correctness of, his theory. That gentleman also spoke of a number of other storms which had occurred in America, the phenomena of which, he also said, were in accordance with that theory. It became, therefore, desirable to inquire into the meteorological facts observed in the British storm, as they were within our reach, not only on account of the intrinsic interest that might attach to them, but as bearing upon, and to a certain extent, testing, Mr. Espy's theory. This inquiry would also enable us to judge, to some extent, how far his mind was liable to be biased, by his theoretical opinions, in his selection of facts. For it should be recollected, that the accounts that may be had recourse to were numerous, and, generally, very vague, and the inquirer had to make his selection from amongst them. Now he would be naturally inclined to think that account the most clear and reasonable that accorded the nearest with his preconceived opinions; while accounts that militate against those opinions would be liable to be put aside, as inconsistent with the supposed laws and general operations of nature. Thus, in extracting what would be called an intelligible account from various obscure sources, that account would be unconsciously moulded to suit the views of the party who made it out. We had no ready means of comparing Mr. Espy's accounts of storms in America with facts respecting them derived from other sources; but it would be not unfair to presume, that the same degree of bias, or of caution in avoiding it, existed in drawing up accounts of those storms, as might be traced in his account of the British storm. That the inquiry might be influenced as little as possible by a bias of this kind, he (Mr. Hopkins) proposed to confine it to the facts given in a pamphlet published shortly after the occurrence of the storm by Mr. E. Smith, of Liverpool, in which were given one hundred and forty-one accounts, taken from the local newspapers in various parts of Ireland, Scotland, and England. The objects of the narrators of these facts were to give accounts of the damage done by the storm, and it was only incidentally that they give meteorological facts. When they did give them, they are brief, and somewhat meagre and obscure; but they were unprejudiced, and so far worthy of confidence. That there might be no unfair selection of these facts, it was proposed to give all that the book contained that were intelligible. But, before going into these facts, it might be well to say a few words on the recognised laws of nature which governed and determined the great general movements of the atmosphere. Dr. Dalton had made us pretty fully acquainted with the nature and properties of those aeriform fluids which constituted our atmosphere, and he also explained the true causes which determined the motions of the two great atmospheric currents which flowed from the equater to the pole, and back again from the pole to the equator; but it was afterwards found, that Hadley had long previously made the same discovery, although it was not generally known. [Hadley's theory was here explained, with the assistance of a terrestrial globe and a diagram.] But, though the theory first made known by Hadley was generally, it was not universally true. The south west was not always the upper, and the north east the lower atmospheric current in the northern hemisphere. In this part of the world, the south west is the prevalent wind in autumn, and the north east prevails in March. In January, that is at the time when our storm occurred, we have fluctuations between the south west and north east currents, sometimes the one and sometimes the other prevailing. On the night of Sunday, January 6th, 1839, the storm more particularly under consideration began its ravages; and Mr. Espy confined his remarks to, and arrowed his map for, the time between ten and twelve o'clock at night. Now, supposing for a moment Mr. Espy's theory to be correct, and supposing also that the storm came from the Atlantic Ocean, it would follow that the storm ought to have been first felt with the wind blowing towards the Atlantic Ocean from every part of the British islands; but nothing of the kind was experienced. Mr. Espy said the storm moved from the south west coast of Ireland, to the north east coast of Scotland. If it did so, at its commencement, a north east wind should have blown at the mouth of the Shannon, and the same north east wind should have been found blowing progressively along the line extending by Limerick, Belfast and Glasgow. But no indication was given, in any of the accounts, of such a wind having been felt. The following were accounts of the weather a little before and up to the time of the commencement of the storm: —

Limerick. It was hoped the storm would have expended its worst rage about twelve o'clock, and abate with the falling water, as high tide came up to ten o'clock on Sunday night; but, contrary to expectation, the gale held on with additional fury.

Kilbeggan. At about a quarter past eleven on Sunday night, the hurricane commenced here; there was at first, a rumbling noise like thunder heard, which was followed by a rushing blast of wind, which swept across the town like a tornado.

Belfast. On Saturday night, after a slight fall of snow, the ground was covered on Sunday morning with a dark dense frost, which about noon on Sunday, began to resolve itself into rain; and this most uncomfortable change of weather continued until about one o'clock next morning.

Isle of Man. On Sunday night last, after a day comparatively mild for the season of the year, this town (Douglas), and indeed the whole Island, was visited by one of the most terrific storms of wind that can be imagined.

Dumfries. Since Friday, we have had every variety of weather, — frost, snow, rain, flood; but these were very bearable alternations, compared with the truly awful tempest that followed. The storm commenced at ten o'clock at night.

Glasgow. So heavy was the fall of snow between Saturday and Sunday morning, that the streets were covered a foot in depth. During the day on Sunday, there was an apparent intermission. The wind subsided for a few hours; but still the atmosphere boded evil, and by ten at night, the elements were again in frightful commotion.

Liverpool. The weather was, for some days previous to, and on Sunday last, somewhat boisterous, though not more so than might be expected at this season of the year. The wind during the day had been about S. S. E., and rather strong. About ten o'clock, P. M., it died away for a short time, and the atmosphere suddenly became unexpectedly mild and warm. In a few minutes, it began to blow with alarming gusts from the south west and W. S. W. The Mercury says, "during the whole of Sunday, the wind blew strongly from the S. S. E., and the glass fell considerably; but many vessels commanded by experienced captains, went to sea, and there was nothing to indicate the frightful storm that followed." Accounts from those who went to sea, substantially agree with the following.

Manchester. On Sunday morning, the weather was frosty, with a slight fall of snow. At noon, the frost disappeared; and during the afternoon and evening, there were occasional showers of rain, with a steady wind at S. S. E., but there was no indication of an approaching storm.

Shrewsbury. Sunday was gloomy; a fall of snow took place about noon, which was followed by several squalls of wind and rain. About eleven at night, the storm commenced.

Huddersfield. On Sunday evening, the weather glass gave palpable indications of a great change in the atmosphere, which was also manifest by the rain and sleet that fell.

Holmfirth. On Sunday evening, a brisk gale blew from the south west, which continued to rise until Monday morning, when it became a complete hurricane.

Bradford. On Sunday, there was a heavy fall of snow, accompanied by occasional gusts of wind; and about six, a rapid thaw set in, attended with heavy rain. This was succeeded about two o'clock on Monday morning, by a high wind, which gradually increased in violence till about five o'clock.

Now in none of these accounts do we find that a north east wind was the herald of the coming storm. The direction of the storm, according to Mr. Espy, was from the south west; and his theory requires, that a wind should meet it, and blow from the north east, as well as from all other points of the compass. The extracts given, show that no such wind blew. We will now see what accounts are given from the same sources of the storm itself, from the commencement to the conclusion.

Kilrush. For many years this coast has not been visited by so severe a storm as that of Sunday night. From the evidence at an inquest, it appeared that the Undine schooner of Limerick, broke from her moorings in Scattery Roads, about ten o'clock on Sunday night, and was driven on shore at Corhadota.

Cork. We were visited on Sunday night, by one of the most tremendous gales of wind ever remembered here. It commenced to blow hard at eight o'clock, from W. S. W.; but at half past eleven, the storm assumed a strength and fury almost irresistible, and continued with unabated violence until six o'clock on Monday morning, when it considerably lulled.

Kingscourt. It commenced here at eleven, last night, (Sunday,) and continued with unabated fury, until seven, this morning.

Dublin. We were visited on Sunday night, with the most terrific storm we ever remember to have experienced. The violence of the wind far exceeded any thing that usually occurs in these regions. There was but little rain, and no thunder or lightning; nothing, indeed, but the wind blowing tremendously and furiously, and continuously, from midnight till after five o'clock, on Monday morning. It began slightly at about seven, in the evening, and rose gradually till twelve, when it came to its height. A more awful night we have scarcely ever past.

Belfast. A previous frost about noon, on Sunday, began to resolve itself into rain, and this continued until about one o'clock, next morning, when it was succeeded by a perfect hurricane. The wind, in the first symptoms of its violence, blew from W. N. W.; but, as its rage increased, it shifted from west to west by north, and augmented in force till finally it settled due south west.

There is no storm from the north east, mentioned in these accounts.

The Meteor Steamer, from Dublin. On the evening of the 6th, (Sunday,) we had reached as far as the Skerries; the wind drawing round strong to the south west, and making little progress. At two, in the morning of the 7th, the wind had veered to west, blowing a perfect hurricane.

Dumfries. The storm commenced at ten o'clock, on Sunday night, and at that time the wind was as near as may be due south. But shortly after one o'clock, on Monday morning, it got round to the west, and, however alarming the gales were previously, they from that time blew with tenfold fury.

Glasgow. The wind subsided for a few hours in the evening; but by ten at night, the elements were again in frightful commotion.

Edinburgh. The hurricane was severe, the wind blowing with such awful fury as to cause a sensible vibration of many of our largest houses; but the damage sustained is trifling compared with that of other places.

No easterly storm in Scotland.

London. Notwithstanding the tremendous gale which commenced about eleven o'clock on Sunday night, and which raged furiously until five o'clock yesterday morning, when it moderated, the shipping on the river sustained but little damage.

Birmingham. In this neighborhood, the hurricane commenced about eleven o'clock on Sunday night, and continued its devastations until daylight the following morning. The wind was chiefly north west, but veered considerably during the night.

Shrewsbury. About eleven o'clock at night, (Sunday,) the storm commenced, and continued roaring with increased violence from the west and south west until eight, A. M., on Monday, shaking by its force the strongest habitations, and making the stoutest heart tremble.

Liverpool. A storm the most awful—whether we consider the violence of the gale, its continuance, the amount of property damaged or destroyed, or the loss of human life with which it was attended—that has taken place in this town, perhaps we may say in the country, for very many years, commenced on Sunday night last, and continued with little intermission till the following afternoon. The wind was from the south west and west south west.

Manchester. Soon after twelve o'clock, the wind began to freshen very rapidly, veering about from south east to south west, and blowing in gusts which rapidly increased in violence until about half past two, when it blew a most violent gale; and its effects began to be apparent in the falling of chimneys and the unroofing of houses. A little after three, it somewhat abated; and many persons flattered themselves that its extreme violence had passed away. This hope, however, was in vain; for about four, the storm again began to rage; and from that time until about half past seven, it resembled one of those awful atmospheric convulsions, which are the scourge of tropical climates, rather than one of the storms of a northern latitude. The storm seems to have raged with the greatest fury between five and six o'clock.

Halifax. Shortly after midnight, on Sunday, the wind began to blow with more than ordinary violence, and rapidly increased to a hurricane, which continued until daylight.

Leeds. The storm commenced about midnight; and from that period till the following afternoon, the most terrific gale of wind we ever remember to have known, was experienced.

Lincoln. At midnight it freshened, and about three there was a roaring hurricane.

Boston. From about two o'clock in the morning until three in the afternoon, the wind blew a perfect hurricane.

Knaresborough. It commenced about two o'clock in the morning, and continued till near the evening with little abatement.

Whitehaven. At this place, it commenced about two, A. M., on Monday, to blow a hurricane from south west to west, and shifted to north west.

York. This morning (Monday) a gale sprung up between three and four o'clock, from the north west, which increased in a fearful manner until six o'clock, threatening the most fearful damage and loss both to life and property. The strong outer wall of the house of correction in this city was blown down.

In the whole of these extracts we find no trace of a north east wind. The greatest violence of the storm seems to have been from the western coast of Ireland, across the Irish sea, Lancashire, and Yorkshire. In Scotland, its violence does not appear to have extended much north of Edinburgh, where it was comparatively moderate. In London again it was quite moderate, compared with what it was two hundred miles further north. But the course, as well as the force, of this storm is particularly marked by certain facts given in these accounts. From Liverpool, across the island to the German ocean, the spray of the sea was carried so abundantly as to leave a large deposit of sea salt on objects exposed to it. It is stated that at St. Helens, Manchester, Rochdale, and Huddersfield, the incrustation was considerable; and the following account is given from Alford, in Lincolnshire, a place near to the German ocean:—

Not within the memory of the oldest person has this place (Alford) been visited with such a tremendous gale as set in from the west on Tuesday morning, the 8th inst., (quære, Monday, the 7th,) about three o'clock, and continued unabated till eleven at night. Every tree and hedge in bleak situations were incrusted over, like a hoar frost, with a powerful alkali, which an eminent chemist pronounced to be muriate of soda. Several times something has been observed within seven or eight miles of the German ocean, when the wind has blown from the east, and it was supposed the wind absorbed it from the vapors of the sea; but the wind now having blown from the west, if such was the case, it must have been conveyed completely across the island from the Irish sea. It appeared that the greater the elevation, the greater was the deposit, which was clearly confined to the bleak side.

But we have equally strong evidence of the force and direction of the wind, in the effect produced on the tides, as shown by the following extracts: —

Whitehaven. The tide rose double its calculated height.

Dumfries. The tide on Sunday rose to an unusual height long before the storm began; and from this circumstance, combined with the extraordinary oscillations of the barometer, we infer that the aerial influences have been at work, with the laws of which we are but little acquainted.

Warrington. On Monday morning, the tide at the bridge rose more than twelve feet above its ordinary height.

Goole. The tide, which would have flowed nine or ten feet, had there been no west wind, did not flow an inch, — it was falling water all day.

Here we see that the wind blew the water upon the western coast, but away from the eastern. If Mr. Espy's account of this storm were correct, the tide and waters of the Humber would have been blown up the river, rather than out of it. It is clear, from the salt spray blown over the land, and the effect of the wind on the tides, that the storm was from the west, or a little to the south of it. There are but few barometrical facts given; but they possess great meteorological interest, as the following extracts will show:—

Glasgow. This morning (Monday) the snow had nearly disappeared; but the rain continued, with the barometer at $27\frac{9}{10}$ inches! — a lower mark than it has indicated for twenty-five years, with one exception. This place is in the track of the centre of the storm, according to Mr. Espy; yet the wind was not very high, and the barometer remained extremely low, after the most violent part of the storm had in this place gone by!

Dumfries. At half past ten on Sunday morning, the glass stood at $29\frac{9}{20}$ inches; at the same hour at night it was $28\frac{13}{20}$ of an inch; and at a quarter past five on Monday morning, it stood at $27\frac{4}{20}$ of an inch. And from the appearance of the surface of the mercury, it must have been $\frac{2}{20}$ths of an inch lower at least.

Here, then, we have at Dumfries the barometer falling from $29\frac{9}{20}$ to $27\frac{4}{20}$, from half past ten on Sunday morning, to a quarter past five on Monday morning, or two and a quarter inches in nineteen and a quarter hours! And this was where the storm was not the most violent; and the last period named was when the storm had passed on.

Colne. On Sunday the barometer was observed to fall very rapidly from "much rain" to "very dry," on the opposite side (that is, from $28\frac{1}{2}$ inches to 27 !); about twelve at night, or half past, the wind began to rise, and to increase in violence till about four o'clock, when it blew a complete hurricane.

Manchester. Here a sudden and rapid fall of the barometer was observed, between nine and twelve o'clock, of, it is said, half an inch.

Rochdale. The storm began about two in the morning, and appeared to be at its greatest height from four to six. About five, the barometer was observed to stand at $27\frac{4}{5}$ inches.

Holmfirth. On Sunday evening the barometer fell rapidly. A brisk gale blew from the south west, which continued to rise until Monday morning, when it became a complete hurricane.

A fall in the barometer, from diminished pressure alone, should cool the air, equal to what it would be cooled by rising to a certain height in the atmosphere. At Dumfries, the fall was $2\frac{1}{4}$ inches or more; and at Glasgow, it was probably nearly as much. A rise in the atmosphere, sufficient to produce a fall of two inches in the barometer, will be about 2,100 feet; and at that height the thermometer will fall, say seven degrees. Now let us see what was the state of the temperature at some of these places, when the barometer fell so low.

Edinburgh. The rapid thaw that took place the same night (Sunday) was also the cause of a good deal of damage to many houses from the sudden influx of the melted snow through the roofs.

Glasgow. The wind became fearful; and, as it brought torrents of rain, the snow went rapidly off, falling from the house tops with a noise like thunder. This morning (Monday) the snow had nearly disappeared.

Liverpool. About ten o'clock, Sunday night, the atmosphere suddenly became unexpectedly mild and warm. In a very few minutes after, alarming gusts of wind began to blow from the south west and west south west. [Extract from the Liverpool Mail.]

Bradford. On Sunday there was a heavy fall of snow, accompanied by occasional gusts of wind; and about six a rapid thaw set in, attended with heavy rain. This was succeeded, on Monday morning, by a high wind, which increased in violence till about five o'clock, when the storm appeared to be at its height.

Lincoln. At ten o'clock on Saturday night, it was a soft air; at midnight it freshened, and at three there was a roaring hurricane.

Here we find, that at the time the barometer fell considerably, the temperature, so far from diminishing, as it would do if Mr. Espy's theory were correct, absolutely increased. It was a soft air at Lincoln. The atmosphere became suddenly mild and warm at Liverpool, when the barometer fell. At Bradford, about six, a rapid thaw set in; and, in Edinburgh and Glasgow, a thaw accompanied the fall of the barometer. In no place is it stated that, as the barometer fell, it became cold! Indeed, it may be presumed, that where the storm raged it was warm; as, if it had been really cold, as shown by the thermometer, the strength of the wind would have caused it to seem very cold to the feelings. Mr. Espy says, that steam is the moving power in storms; but, if so, that moving power may be modified by various circumstances. In January the dew point is commonly as low as 32°, and in summer it rises to 60°. Now the quantity of steam in the atmosphere, when the dew point is 32°, is $\frac{1}{240}$th of the whole atmosphere; when the dew point is 52°, it is $\frac{1}{120}$th; when 73°, it is $\frac{1}{60}$th, or four times the quantity at 32°.

We see, then, that there is a much smaller supply of this moving power in winter than in summer, and yet the greatest storms occur in winter. The great atmospheric currents are very much stronger in the winter than in the summer; may it not be that some cause acts upon these currents when at their superior strength? Suppose an upward current, such as that described by Mr. Espy, to interrupt the progress of the upper current of the atmosphere, and cause it to descend to the surface of the earth, would not such a descent produce all the phenomena which were experienced during the storm of which we are speaking? A general review of all the facts given, respecting this storm, warrants the following conclusions: That the weather had been cold and windy before the storm, but not uncommon for the season. That the storm was felt the earliest on the western coast of Ireland, coming from the west; then in Scotland, later in England, and lastly in Denmark, always proceeding from the west. The line of greatest damage was from near the Shannon to the mouth of the Humber. From Liverpool to Alford, in Lincolnshire, salt spray was carried in large quantities across England, and the tides were thrown up on the land on the western coast of Lancashire, and from land on part of the eastern coast of Yorkshire and Lincolnshire; and the barometer showed diminished atmospheric pressure where the temperature was warm. But it is to be hoped, that at no distant period we shall have observers who will more carefully register meteorological facts during storms, and that they will come to a better understanding respecting the kind of facts to be noted and the form of giving them.

Reply to Mr. Hopkins, by a gentleman in Liverpool.

204. The principal objection made by Mr. Hopkins, against Mr. Espy's theory of storms, is predicated on a statement of Mr. Hopkins himself, which statement is not at all in accordance with Mr. Espy's views.

Mr. Hopkins asserts that "Mr. Espy said, that the storm moved in a line from the south west coast of Ireland to the north east coast of Scotland. If it did so, at its commencement. a north east wind should have been found blowing progressively along the line extending by Limerick, Belfast and Glasgow, but no indication was given in any of the accounts, of such a wind having been felt."

I was much surprised, on reading this paragraph, because I had heard Mr. Espy, in his lectures here last summer, strongly controvert the idea that wide extended storms travel towards the north east in this latitude, and in the latitude of Pennsylvania; and as Mr. Hopkins referred to the explanation of the theory in question given by Mr. Espy at the late meeting of the British Association, I immediately turned to the report of his statement in the Athenæum, and found the following sentence in the very beginning of his paper. "Mr. Espy commenced by stating that he had found in the great storm of the sixth and seventh of January, 1839, that the wind changed and the barometer fell sooner on the north west parts of Great Britain, than on the south east; and from these two circumstances he thinks it highly probable that this storm moved not exactly towards the east but a little south of east, and if so, it would be similar to some storms, which he had examined in the United States.

Now if Mr. Hopkins had given this view of Mr. Espy's theory, all the arguments which he uses against the theory on this point would really be in its favor, provided it is true, as Mr. Espy says it is, that the wind set in south of east on the south east coast of England, violent when it was raging north west in the western part of Scotland, and south west in the south western parts of England. For if the storm was of great diameter from the N. N. E. to S. S. W. and moved towards the south of east, the wind ought to set in from some point south of east. And Mr. Espy says in another part of his paper, "As the wind in the first part of the storm is frequently south east, and in the last part of the storm north west; and as the barometer falls successively from north of west, to south of east, it seems highly probable that these storms of oblong form move towards the south of east."

Now if the reader will turn to the Shipping and Mercantile Gazette of the 8th, 9th, 10th, and 11th January, and the Edinburgh Advertiser of the 8th, he will find that the wind became piercingly cold at Edinburgh from the east, on the evening of the sixth, and afterwards changed to an opposite direction; and that at Bridlington the wind got south east in the night of the sixth, blowing a gale, fell moderate about midnight and about three next morning the awful scene commenced, wind west, and at Sunderland they had on the seventh a heavy gale from the S. S. E. to south west.

Another objection, brought forward against Mr. Espy's theory is that "at Glasgow, though it is in the track of the centre of the storm, according to Mr. Espy, yet the wind was not *very* high, and the barometer remained extremely low after the most violent part of the storm had in this place gone by." Now it would appear that Mr. Hopkins here drew a deduction contrary to the evidence which he himself furnishes in another paragraph, where it is said, "Glasgow — the wind became fearful."

As to the barometer continuing very low after the storm passed on, this would easily be accounted for by the continuation of bad weather, and the evolution of the latent caloric during the condensation of the vapor into cloud. And as to the fact that the wind was much more violent from the westward in the latter part of the storm than at the beginning it was from the eastward, this will generally be the fact, as this is the direction of the wind in general, and especially if there had been a strong westerly wind just before the approach of the storm, which was the case in this very storm. I have seen a letter of S. D. Sollet, Esq., a highly respectable teacher of Hull, giving a minute description of the storm from personal observation, in which he says, "the wind was still W. S. W. at eleven, P. M., but got round to S. S. E., and at thirty minutes past two, A. M., of the seventh, was a high gale, S. S. E., and blew off about two hundred tiles from the top of his building, about that time; at four, the wind was south, very violent, and at five, W. S. W., chimneys falling in every direction."

As to the objection urged against Mr. Espy's theory, "that at the time the barometer fell considerably, the temperature, so far from diminishing as it would do if Mr. Espy's theory were correct, absolutely increased;" it is difficult to know what Mr. Hopkins means.

He acknowledges what has long been known, "that a fall in the barometer from diminished pressure, alone would cool the air, equal to what it would be cooled, by rising to a certain height in the atmosphere."

This is demonstrated by experiment, therefore it is certain that the air was several degrees colder, on that memorable night, when the barometer was at its minimum, than it would have been under the ordinary pressure. It seems to be rather according to Mr. Hopkins's mode of reasoning than Mr. Espy's, that the temperature ought to have been colder than ordinary when the barometer fell, for Mr. Hopkins assigns no reason for an increase of temperature at the time, whereas Mr. Espy shows in his paper a cause why very warm puffs of air should sometimes occur in great storms, with cessation of rain, notwithstanding the fall of the barometer, and the cold which the expansion of the air due to that fall produces.

Another objection to the theory is the following. "Mr. Espy says that steam is the moving power in storms, but there is a much smaller supply of this moving power in winter than in summer, and yet the greatest storms occur in winter." This objection is plausible, but not unanswerable. It is undoubtedly true according to Mr. Espy's theory, that the violence of a storm, all other things being equal, should be in proportion to the quantity of vapor or steam power in the air at the time. And at no season of the year is there ever a violent storm, unless the dew point is very high, *for the season.* But the violence of the motion upwards under a storm, depends not merely on the steam power in the air, but also on the coldness of the air on the outside of the cloud when compared with the temperature of the air in the cloud itself. Now this difference may even be greater in winter than in summer.

To produce the most violent hurricanes, however, requires a higher dew point than ever occurs in the British Isles. They only take place in low latitudes, such as the West Indies, and the Indian Ocean, &c., where the quantity of vapor near the surface of the sea is sometimes one forty-eighth of the weight of the air containing it. Mr. Hopkins's chief objection seems to be that the air does not blow in on all sides towards the centre of a storm.

He does not pretend to deny that if the air did rise in the centre it would form cloud by the cold of expansion, for this seems to be generally admitted, and is demonstrated by experiment. Nor does he contradict Mr. Espy's great principle, on which his whole theory is founded, one which he demonstrates both on acknowledged chemical principles, and by experiments with the nephelescope, that latent caloric enough is given out into a great storm cloud by the vapor condensed in forming the cloud to cause the barometer to fall as much as it actually does in great storms. Now, when it is known that the storm was very violent from the west as early as nine o'clock, on the coast of Ireland, and that the wind continued to blow from that quarter for several hours, while at the same time, on the eastern coast of England and Scotland, the wind was getting round to the eastward, increasing in violence at Hull, and blowing a gale south east at Bridlington, I would ask Mr. Hopkins what became of the mighty quantity of air rushing towards England across Ireland for four or five hours?

Did it spread out at the north and south? So far from this being the case there was a violent wind all night all along the southern coast of England, from the southward. And at Aberdeen, George Innes, in his journal, says, the wind, from being calm before, began to blow heavily from the north west towards night, and in the early hours of Monday, nearly a hurricane N. N. W. And all the accounts from the west of Scotland give the wind north of west after the change. The air, therefore, which blew with such violence from the west on the western coast of England till about midnight, must have gone upwards before it reached the eastern coast; and all the phenomena of cloud forming, and giving out latent caloric, as demonstrated by Mr. Espy, must have taken place.

Indeed, as Mr. Espy says in his lectures, if the wind had even been from the west on the eastern coast; but moderate during the hours of great violence from the west, on the western coast, even then there must have been an upward motion of the air over England, and the generation of cloud, &c., would have been the result.

In conclusion, I would remark that the simplicity of the theory, and the beautiful explanation which it gives of a vast variety of phenomena, afford a strong presumption in favor of its truth.

SECTION TENTH.

ARTIFICIAL RAINS.

[From the National Gazette.]

204. MESSRS. EDITORS, — Knowing the difficulty, if not the impossibility, of making the subject intelligible in a short newspaper article, it is with reluctance that I am now induced, after much earnest solicitation from my friends, both near and remote, to give a very brief summary of the reasons and FACTS, which have led me to desire, that an experiment should be made to see whether *rain may be produced artificially in time of drought.*

The documents which I have collected on this subject, if they do not prove that the experiment will succeed, do at least prove that it ought to be tried; this, I trust, will most satisfactorily appear when they shall be published entire. In the meantime it has become necessary to present to the public something on the subject, lest longer silence might be construed into an abandonment of the project.

First, — It is known by experiment, that if air should be expanded into double the volume by diminished pressure, it would be cooled about 90° of Fahr.

Second, — I have shown by experiment, that if air at the common dew point in the summer season in time of drought, 71°, should go up in a column to a height sufficient to expand it by diminished pressure into double the volume, it would condense into water or visible cloud, by the cold of expansion, more than one half of its vapor — a quantity sufficient to produce nearly three inches of rain.

Third, — It is known by chemical principles, that the caloric of elasticity given out during the condensation of this vapor, would be equal to about 20,000 tons of anthracite coal burnt on each square mile over which the cloud extended.

Fourth, — I have shown by experiment, (see Saturday Courier, March 18, 1837,) that this caloric of elasticity would prevent the air from cooling only about half as much as it would, if it had no vapor in it, or about 45° at the height assumed; which would cause the air in the cloud to be, at that height, about 45° warmer than the air on the outside of the cloud at the same height. I have shown from these principles, (see Journal of the Franklin Institute for 1836,) that the barometer would fall under the cloud thus formed, in favorable circumstances, a quantity as great as it is known to fall sometimes under the middle of a dense and lofty cloud, and that consequently the air would rush in on all sides towards the centre of the cloud and upwards in the middle, and thus continue the condensation of the vapor and the formation of cloud and the generation of rain. (See also Journal of the Franklin Institute for September and October, 1838, and for January, February and March, and subsequent, 1839.)

Fifth, — I have shown also in the volumes quoted above, that the air does move inwards on all sides towards the centre of the space or region where a great rain is falling, and of course upwards, after it comes in under the cloud, which is so much lighter than the surrounding air; at least, that it does so in all storms which have been investigated, which now amount to sixteen, besides several tornadoes, in all of which the trees were thrown with their tops inwards.

From the principles here established by experiment, and afterwards confirmed by observation, it follows, that if a large body of air is made to ascend in a column, a large cloud will be generated, and that that cloud will contain in itself a self-sustaining power, which may move from the place over which it was formed, and cause the air over which it passes, to rise up into it, and thus form more cloud and rain, until the rain may become more general; for many storms which commence in the West Indies, very narrow, are known to move from the place of beginning, several thousand miles, widening out and increasing in size, until they become many hundred miles wide. (See Redfield and Reid, and the Reports of Joint Committee.)

If these principles are just, it will follow, when the air is in a favorable state, that the bursting out of a volcano ought to produce rain; and such is known to be the fact; and I have abundant documents in my possession to prove it. Some are given below.

So, under very favorable circumstances, the bursting out of great fires ought to produce rain; and I have many facts in my possession rendering it highly probable, if not certain, that great rains have sometimes been produced by great fires.

It is a general opinion in parts of the country where great fires frequently take place, that those fires produce rain. Now this opinion could hardly have originated without some circumstances besides mere coincidence attending them, such as related in the following account. Mr. Dobrezhoffer, a missionary to Paraguay, speaking of the tall grass and bulrushes on fire, says: — "I myself have seen clouds and lightning produced from the smoke, as it is flying off *like a whirlwind;* so that the Indians are not to blame for setting fire to the plains in order to produce rain, they having learned that the thicker smoke turns into clouds which pour forth water." (Account of the Abiphones, vol. 3d, page 150.)

Mr. Lapice, of Louisiana, informed Dr. S. Calhoun, of Philadelphia, "that the conflagration of the long grass in the prairies of that State covers every thing with its cinders for miles around, and that rain follows it shortly, according to immemorial observation in that country."

"Very extensive fires in Nova Scotia, in the woods, are so generally followed by heavy floods of rain, that there is some reason to believe that the enormous pillars of smoke have some share in producing them." [Mag. Nat. Hist. for Dec., 1835.]

The bad philosophy of supposing that smoke was turned into cloud and produced rain, does not weaken the evidence of the main fact.

If the principle is correct, that clouds are formed by up-moving columns of air, we should expect to find, in favorable states of the air, that clouds would form over large cities and manufacturing towns where much fuel is burnt; and so we find it to be.

Extract of a letter to me from Benjamin Matthias of Philadelphia:

"In the course of the last winter, while in England, I visited Manchester four or five times, and on each day it rained. Several of the inhabitants assured me that it rains in Manchester more or less every day in the year."

Extract from Edward Mammatt's Collection of Facts concerning Ashby Coal Field. 4to. London: 1836:

"When the air is apparently stagnant in the valley of the Thames and surrounding country, a strong current is found to set in, on every side of London, along the streets leading from the country, in the morning. This current is no doubt occasioned by the rarefaction in the high chimneys over so many thousand fires just kindled, and must be the cause of the introduction of fresh air to an immense extent, which would not otherwise flow. This rarefaction produces other phenomena, among which, when the atmosphere is in a light state, and clouds are passing at a height which does not allow them to condense and fall in rain, these accumulate in passing over London, and either remain as a dense fog, or drop in small rain all day long, scarcely clearing once; the country, at a little distance, having very little rain."

The bad philosophy of supposing the air so light on these occasions as to let the clouds on passing sink down in it over London, does not invalidate the evidence of the principal fact.

From these remarkable facts alone, I think it will be acknowledged that there is some connection between great fires and rains other than mere coincidence, even if that connection remained a mystery. Humboldt acknowledged this in the case of volcanoes, when he speaks of the *mysterious* connection between volcanoes and rain, and says that when a volcano bursts out in South America in a dry season, it sometimes changes it to a rainy one. But now, when it is demonstrated by the most decisive evidence, the evidence of experiment, that air, in ascending into the atmosphere in a column, as it must do over a great fire, will cool by diminished pressure, so much that it will begin to condense its vapor into cloud as soon as it shall rise about as many hundred yards as the temperature of the air is above the dew point in degrees of Fahr., it amounts to a very *high* probability that great fires have *sometimes* produced rain. That great fires and even volcanoes should not *always* produce rain is manifest from the circumstance that, as they break out accidentally, they may sometimes occur when the state of the atmosphere is unfavorable, and even adverse to rain. First, if they should break out when there is a current of air, either near the surface of the earth, or at a considerable distance above, of some strength, the upmoving column would be swept by it, out of the perpendicular, before a cloud of great density could be formed, and thus rain would be prevented.

Second, they might break out when the dew point was too low to produce rain at all; and, third, there may sometimes be an upper stratum of air, containing so much caloric that its specific levity would prevent the upmoving column from rising into it far enough to cause rain.

These three things, I conceive, are the only circumstances which prevent great fires from producing rain at all times when they occur. The first two can be ascertained without much difficulty by means of small balloons and the dew point; the last, in the present state of science, cannot always be known, and a failure on that account must be risked by the experimenter.[1] This risk I am willing to run, if Congress or the State legislature will promise a sufficient reward *in case of success.*

It has been objected to my project that I propose too much, and that it is utterly absurd to expect to make it rain in time of drought, when there is such a scarcity of vapor in the air.

Now, this objection is founded on an entire ignorance of the fact, arising from a want of due consideration. For there is *generally* more vapor in the time of summer drought, than at any other time, as I know by experiments constantly made almost every day for these last ten years; and this is reasonable in itself, for the vapor is rising into the air and increasing every day of dry weather, preparing for another rain. A quiet state of the atmosphere is also more likely to occur, to great heights, in time of droughts than at any other time, for immediately after rains there are sure to be cross currents of air, produced by the inward motion of the air at the lower part of the cloud, and an outward motion in the upper part, which require some time after the rain to come to rest.

If I have succeeded in showing that there is any the least ground to hope that an attempt to produce rain, might sometimes succeed under favorable circumstances, and that those

[1] This difficulty will probably be overcome by Pouillet's Actinometer, lately invented.

favorable circumstances are more likely to occur in time of drought than at any other time, then it follows that the experiment is a highly interesting one, and ought to be immediately tried. If it should be successful, who can tell the mighty results which may follow in its train?

I have many reasons and facts which induce me to believe that if a very large cloud is once generated, the rain will become general, or at least spread over a wide extent of territory; and who can tell, *à priori*, that this will not be the case, when it is now known that an immense steam power is let loose in the formation of such a cloud; a power which can be calculated with as much accuracy as that of the steam engine itself, and in part on the same principle.

Gentlemen have made their puns on this project, and had their laugh; and I am sorry to see by letters which I have received, that my friends and relations at a distance are much troubled at these innocent laughs; but let them be consoled; I have laughed too, well knowing that those who laughed the most heartily, would be the most willing to encourage the experiment, as soon as they discovered they had nothing to laugh at. As a proof that I was right in this anticipation, I may be permitted to say that I have lately received a letter from a highly distinguished member of the American legislature,[1] who laughed as heartily as *any* one when my petition was presented there, containing many kind expressions, and promising me by way of amends for his levity, "to avail himself of the earliest opportunity of being better informed on the subject of my new philosophy." Such conduct as this is all I want; I fear not the strictest scrutiny.

If I should be encouraged to go on with the experiment, I mean to have a large mass of combustibles prepared ready for use, and when I have found all the circumstances, men-

[1] Hon. J. J. Crittenden.

tioned before, favorable in a time of drought, I would set fire to the circumference in various places at once. Soon after the fire commences, I will expect to see clouds begin to form, about as many hundred yards high as the temperature of the air is above the dew point in degrees of Fahrenheit. I will expect to see this cloud rapidly increase in size, if its top is not swept off by a current of air at a considerable distance above the earth, until it becomes so lofty as to rain. I shall expect the cloud to move eastwardly, increasing in width as it advances; and the next day I shall expect the region to the south of where the rain fell, to be visited by rain; for a reason explained in my writings.

But it is in vain to anticipate all the results which will follow, for nothing but the experiment itself can demonstrate them. If the experiments, when repeatedly tried, should fail, it would be in vain for me to say I would not be mortified, but I will not incur any disgrace—unless it is disgraceful to desire to see a great experiment made, which all the knowledge we have on the subject, in the present state of science, leads us to hope will be crowned with success.

I have made this very brief, though necessarily imperfect statement of my reasons for wishing to see the experiment tried, which can alone decide the question, to comply with the earnest and repeated solicitations of my friends; I will now in conclusion say a word for myself.

The present state of the science of meteorology renders it highly important to know in what direction and with what velocity summer rains travel over the surface of the earth. What is their shape — round or oblong — and if oblong, in what direction their transverse diameter lies, and whether they move side foremost or end foremost or obliquely. Now I request gentlemen throughout the United States, who feel interested in this subject, to keep a journal of all rains from the beginning of June till the end of September; noting their beginnings and endings, the force and direction of the winds, and also of the clouds, and send the accounts, (published in some paper,) as early in October as convenient, to William Hamilton, Esq., Actuary of the Franklin Institute, Philadelphia.

Finally, if any gentleman intends to clear from twenty to fifty acres of woodland this spring, or early in the summer, in the western or north western parts of Pennsylvania, will he please to inform me of the fact as soon as convenient.

Journals of the weather also for the 16th, 17th, and 18th of March, 1838, kept in various parts of Virginia and North Carolina, are much desired; and if gentlemen can even tell me how the trees are thrown down, indicating the direction of the wind, the information will be highly valuable, and should not be withheld, if nothing else is known or recollected.[1]

I am, gentlemen, yours respectfully,

JAMES P. ESPY.

Philadelphia, April 2d, 1839.

Documents referred to in Article 204.

[Sir William Hamilton on the eruption of 29th September, 1538, which formed Nuevo Monte, p. 127.]

205. First then, (says Marco Antonio delle Falconi,) will I relate simply and exactly the operations of nature, of which I was either myself an eye witness, or as they were related to me by those who had been witnesses of them. It is now two years that there have been frequent earthquakes at Pozzuolo, at Naples, and the neighboring parts; on the day and in the night before the appearance of this eruption, above twenty shocks, great and small, were felt at the above mentioned places. The eruption made its appearance the 29th of September, 1538, the feast of St. Michael the angel. It was on a Sunday, about an hour in the night; and, as I have been informed, they began to see on that spot, between the hot baths or sweating rooms, and Trepergule, flames of

[1] This information would still be valuable: and so of any additional facts concerning any storm investigated in this volume.

fire, which first made their appearance, at the baths. Then extending towards Trepergule, and fixing in the little valley that lies between the Monte Barbaro and the hillock called del Pericolo, which was the road to the lake of Avernus and the baths. In a short time the fire increased to such a degree, that it burst open the earth in this place, and threw up so great a quantity of ashes and pumice stones, mixed with water, as covered the whole country, and in Naples a shower of these ashes and water fell a great part of the night. The next morning, which was Monday, and the last of the month, the poor inhabitants of Pozzuolo, struck with so horrible a sight, quitted their habitations, covered with that muddy and black shower, which continued in that country the whole day, flying death, but with faces painted with its colors; some with sacks full of their goods, others leading an ass loaded with their frightened family towards Naples; others carrying quantities of birds of various sorts that had fallen dead at the time the eruption began; others again with fish which they had found, and were to be met with in plenty upon the shore, the sea having been at that time considerably dried up. Don Petro di Toledo, viceroy of the kindgom, with many gentlemen, went to see so wonderful an appearance; I also, having met with the most honorable and incomparable gentleman, Signior Fabritio Moramaldo, on the road, went and saw the eruption and the many wonderful effects of it. The sea towards Baia had retired a considerable way; though from the quantity of ashes and broken pumice stones thrown up by the eruption, it appeared almost totally dry. I saw, likewise, two springs in those lately discovered ruins, one before the house which was the queen's, of hot and salt water; the other of fresh and cold water, on the shore, about 250 paces nearer to the eruption: some say, that still nearer to the spot where the eruption happened, a stream of fresh water issued forth like a little river.[1] Turning to-

[1] See Section IX., for explanation.

wards the place of the eruption, you saw mountains of smoke, part of which was very black, and part very white, rise up to a great height; and in the midst of the smoke, at times, deep colored flames burst forth with huge stones and ashes, and you heard a noise like the discharge of a number of great artillery. It appeared to me as if Tyhæus and Enceladus from Ischia and Ætna, with innumerable giants, or those from the Campi Phlegrei, (which according to the opinions of some, were situated in this neighborhood,) were come to wage war again with Jupiter. The natural historians may perhaps reasonably say, that the wise poets meant no more by giants, than exhalations, shut up in the bowels of the earth, which, not finding a free passage, open one by their own force and impulse, and form mountains, as those which occasioned this eruption have been seen to do; and methought I saw those torrents of burning smoke that Pindar describes in an eruption of Ætna, now called Mon Gibello in Sicily; in imitation of which, as some say, Virgil wrote these lines "*Ipse sed horrificis juxta tonat Ætna ruinis*," &c. After the stones and ashes with clouds of thick smoke had been sent up by the impulse of the fire and windy exhalation, (as you see in a great cauldron that boils,) into the middle region of the air, overcome by their own natural weight, when from distance the strength they had received from impulse was spent, rejected likewise by the cold and unfriendly region, you saw them fall thick, and, by degrees, the condensed smoke clear away, raining ashes with water and stones of different sizes according to the distance from the place; then by degrees, with the same noise and smoke, it threw out stones and ashes again, and so on by fits. This continued two days and nights, when the smoke and force of the fire began to abate. The fourth day, which was Thursday, at 22 o'clock, there was so great an eruption, that, as I was in the Gulf of Purroli coming from Ischia, and not far from Misenum, I saw in a short time, many columns of smoke shoot up with the most terrible noise I ever heard, and, bending over the sea, came near our boat, which was four miles or more from the place of their birth; and the quantity of ashes, stones and smoke seemed as if they would cover the whole earth and sea. Stones, great and small, and ashes, more or less, according to the impulse of the fiery exhalations, began to fall so that a great part of this country was covered with ashes and many that have seen it say they reached the vale of Diana, and some parts of Calabria, which are more than one hundred and fifty miles from Pozzuolo. On Friday and Saturday nothing but a little smoke appeared, so that many taking courage went upon the spot, and say that with the stones and ashes thrown up, a mountain has been formed in that valley not less than three miles in circumference, and almost as high as the Monte Barbaro, which is near it, covering the Cenattaria, the castle of Trepergule, all those buildings and the greatest part of the baths that were about them ; extending south towards the sea, north as far as the lake of Avernus, west to the Sudatory, and joining east to the foot of the Monte Barbaro; so that this place has changed its form and face in such a manner as not to be known again, a thing almost incredible to those who have not seen it; that in so short a time so considerable a mountain could have been formed. On its summits there is a mouth in the form of a cup, which may be a quarter of a mile in circumference, though some say it is as large as our market place at Naples, from which there issues a constant smoke; and though I have seen it only at a distance, it appears very great. The Sunday following, which was the 6th October, many people going to see this phenomenon, and some having ascended half the mountain, others more, about two o'clock, there happened so sudden and horrid an eruption, with so great a smoke, that many of the people were stifled, some of which could never be found. I have been told that the number of dead and lost amounted to twenty-four.

From that time to this, nothing remarkable happened. It seems as if the eruption returned periodically, like the ague or gout. I believe henceforward it will not have such force, though the eruption of the Sunday was accompanied with showers of ashes and water which fell at Naples, and were seen to extend as far as the mountain of Somma, called Vesuvius, by the ancients, and, as I have often remarked, the clouds of smoke proceeding from the eruption, moved in a direct line towards that mountain, as if these places had a correspondence and connection one with the other.[1] In the night, many beams and columns of fire were seen to proceed from this eruption, and some like flashes of lightning. We have then many circumstances for our observation, the earthquakes, the eruption, the drying up of the sea, the quantity of dead *fishes and birds*, the birth of springs, the shower of ashes with water and without water, the innumerable trees in that whole country, as far as the Grotto of Lucullus, torn from their roots, thrown down and covered with ashes, it gave one pain to see them, and all these effects were produced by the same cause that produces earthquakes.

In page 82, he says, on a visit to Mount Ætna: We saw the evident marks of a dreadful torrent of hot water that came out of the great crater at the time of an eruption of lava in the year 1755. Luckily this torrent did not take its course over the inhabited parts of the mountain; as a like accident on Mount Vesuvius, in 1631 swept away some towns and villages in its neighborhood, with thousands of their inhabitants. The common received opinion is, that these eruptions of water proceed from the volcanoes having a communication with the sea; but I rather believe them to proceed merely from depositions of rain water in some of the inward cavities of them.

The reader, I think, will have but little doubt that these torrents of fresh water were produced in the same manner

[1] Carried by the upper current of the air towards the east.

as those in the white mountains and at the peak of Teneriffe, &c. [Sec. VIII.]

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206. About the first of June, 1783, three columns of flame rose up from Iceland, and presently united, when they could be seen thirty-four miles off, when the flame was not covered by thick vapor. On the 11th June, the fiery column, which had vanished for a little, again made its appearance, and could be distinctly seen at the distance of thirty or forty miles; its thundering noise could be heard at the same distance, and continued the whole summer. The above column was accompanied the same day by a violent rain. The places in the neighborhood of this column were at the same time exposed to violent cold, snow, and hail of uncommon size; but as the column extended further, these were succeeded by a scorching and almost insufferable heat, and the sun appeared like a red globe. This heat continued for several days without interruption, and returned several times in succession. The rain occasioned infinite damage, because the water in many places swept off whole pieces of soil, and carried them with it into the deep gulfs.

The sails and decks of several ships, while on their passage between Copenhagen and Iceland, were covered with black sandy dust: even in Zeland and Copenhagen the sun, from the beginning of June till the 8th of August, seemed remarkably red, and throughout the whole month of July the atmosphere was so filled with dust and vapor that the sun was red at noon, and could not be seen in the evening at eight or nine o'clock. [Tilloch's Magazine.

In an eruption on the 25th of December, 1817, there was a hail storm accompanied with red sand. [Quarterly Jour. Sci. Lit. and Arts, Vol. 5, p. 201.

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207. Captain Tillard, describing an eruption of a volcano

in the sea, near the Island of St. Michael, on the 12th of June, 1811, says, "as the impetus, with which these columns of smoke were severally propelled, diminished, and their ascending motion had nearly ceased, they broke into various branches resembling a group of pines, these again forming themselves into festoons of white feathery smoke, in the most fanciful manner imaginable, intermixed with the finest particles of falling ashes, which at one time assumed the appearance of innumerable plumes of black and white ostrich feathers surmounting each other; at another, that of light wavy branches of a weeping willow.

"During these bursts, the most vivid lightning continually issued from the densest part of the volcano; and the cloud of smoke ascending to an altitude much above the highest point to which the ashes were projected, rolled off in large masses of fleecy clouds, gradually expanding themselves before the wind in a direction nearly horizontal, and drawing up to them *a quantity of water-spouts*, which formed a most beautiful and striking addition to the general appearance of the scene." [Tilloch's Mag., Vol. 39, p. 452.] And at page 229, vol. 38, it is said, these water-spouts, after spreading themselves in the air, fell in a heavy rain, accompanied with vast quantities of fine black sand, which completely covered the Sabrinas's deck, at the distance of three or four miles from the volcano.

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208. "The besiegers, wishing to set the town on fire, procured for this purpose a large number of faggots. They tossed them from their own mound into the space between the wall and inner fortification.

"As many hands were employed in this business, they soon filled it up, and then proceeded to toss more of them into the other parts of the city lying beyond, as far as they could by the advantage given to them by the eminence. Upon these they threw fiery balls made of pitch and sulphur, which caught the faggots, and soon kindled such a flame as before this time no one had ever seen kindled by the art of man: and the Plateans, who had baffled all other efforts, very narrowly were delivered from perishing by its fury. . . . . It is now reported that a heavy rain, falling on a sudden, attended with claps of thunder, extinguished the flames and put an end to this eminent danger." [Siege of Platea, Thucidides, book 2, page 81, of Smith's version.

"In the year 1779, a party of British came into Connecticut and plundered New Haven, where Yale College is situated. They burned Fairfield and Norwalk, and some other places. Fairfield was burned just at evening. A thunder storm came up at the same time and added greatly to the horrors of the scene." [History of the United States.

TREMONT HOUSE, June 18, 1839.

JAMES P. ESPY, ESQ.,

209. DEAR SIR, — Observing that you are about to deliver a course of lectures in Boston, I deem it not impertinent to relate a conversation which I recently had with my brother, who spent the last winter in Florida.

My brother informed me, that it was the practice of the planters there, to set fire to the reeds, brush wood, and tall grass, which cover the marshes in that country, and that those fires were generally succeeded by copious rains. He spoke of one instance in particular, when a large mass of wood, which had been collected together, to the extent of from one to two thousand cords, and being fired, produced an immense column of blaze and smoke, extending to a great height, immediately after which, clouds began to form in all directions, and rain fell in such torrents, that before morning, the fire was completely extinguished; leaving the large trunks of the trees unconsumed.

I have written to my brother, and requested him to furnish you some further particulars; I presume he will write to you. The place where these fires occurred, was near the mouth of St. John's river, on the Atlantic coast, in lat. 30°, north. Yours, truly,

THOMAS FLETCHER.

When king Charles was at Belvoir, his chamberlain, Lord Pembroke, wrote to the high sheriff of Staffordshire, the king's commands, that no fern should be burnt at the time he was about to visit them, as he understood it brought down rain. [Gardiner's *Music and Friends*, vol. 1, page 408.

Benjamin Matthias, Esq., to Mr. Espy.

PHILADELPHIA, December 4th, 1838.

210. DEAR SIR, — I am ignorant whether or not the circumstance may have any bearing upon your system of the "*Philosophy of Storms*," but while in England, last winter, I was struck with the peculiar and almost constant humidity of the atmosphere, in and about the town of Manchester. In the course of the winter, I visited this town on four or five different occasions, and on each day it rained. Several of the inhabitants assured me, that it rains in Manchester, more or less, every day in the year, and I am inclined to believe that such is the fact, or at least, that rain falls on six days out of seven.

Manchester, as you know, is an extensive manufacturing town. It lies on low ground, on a small river, and is surrounded by hills. An immense quantity of bituminous coal is daily consumed in the manufactories, and the atmosphere over the town, is surcharged with a smoke sufficiently dense, in general, to obscure the rays of the sun.

Extract from the "Spirit of the East," vol. 11, *page* 108.

211. The tract of country between Jericho and the Jordan, is covered with a grass, not above six or eight inches

in height, but exceedingly inflammable, giving a bright light; it is always dry and like tinder at this season of the year; the caravan is preceded and followed by men with torches, who set this grass on fire; it then burns on both sides along their path, producing the most singular and splendid effect. Strange stories are told of the saints who have furnished this district with a plant so admirably adapted to give splendor to this nightly pilgrimage of devotion. Strange stories are also told of the furious storms and the torrents of rain that impious Giouls have aroused in the welkin to quench the flame that guided the pilgrim on his pious way. Such a storm overtook the caravan with which my faithful Hadji went a sinner, and returned a saint.

KANAWHA COURT HOUSE, July 17, 1839.

212. SIR, — Some months ago I was in company with Mr. Thomas Matthews, one of our old and respectable citizens. In the course of conversation he related to me the following fact. "When I was a young man, in the early settlement of Kentucky, I went to see a friend who had ten acres of land which had been covered with a luxuriant growth of timber, cut while in the leaf; the brush had been piled, and had remained so, until the whole had become very dry. In the month of August, after a long dry season, it was proposed to set fire to the "clearing;" the day was clear, not a cloud to be seen, and was selected for its *calmness*, for fear the fire would damage other property. Well, all hands were called, fire obtained, many of us went to work, the leaves were so dry the brush ignited with great rapidity; in a few minutes the whole circle of the *clearing* was on fire; very soon a strong wind set in from all points of the compass; the smoke and flame assumed an upward gyral motion ('*like a whirlwind*,') a cloud was soon formed, and a fine rain fell for some miles around. I was convinced that rain was produced by that fire."

He is a man of truth, and his statement may be relied on implicitly.

I deemed this a case proving your theory so triumphantly, I have been induced to give you the facts as I received them. Yours, truly, JAMES A. LEWIS.

P. S. I am well known to many of your merchants in Market Street; Thomas Shewell, Field Fobes, Richard Ashtrast, William Wilson, &c.

The author waited on some of these gentlemen, and satisfied himself that Mr. Lewis was known to them.

Facts for Mr. Espy.

213. The following facts are distinctly recollected as generally admitted, observed and spoken of by my fellow citizens, inhabitants of the counties of Delaware and Otsego, in the state of New York, while I resided in those counties, from A. D. 1819 to A. D. 1827.

These counties are situated on the eastern branch of the Susquehannah river, by which they are separated from each other.

The face of the country is broken, hilly, mountainous, and diversified; hills rising on hills, on either side of the river, till they assume decided claims to the character of mountains. This being an outline of the prevailing face of the country, it will be manifest that extensive prospects and landscapes will be commanded by the eye from many locations. At the time referred to, many of the inhabitants were engaged in clearing their land of the incumbering timber. Extensive fallows, as they were called, were, every year prepared for the redeeming fire, by the industrious woodman's axe, and were accordingly burnt over at suitable times and seasons. Or, in other words, when the timber, brush and combustibles were dry, and favorable to the operation.

1. As will naturally be presumed, the fallows were set on fire in dry weather; and as several hours, or even a day or two were requisite for the work, no fair prospect of rain was waited for, before the fires were set. Often, if there was a prospect of rain soon, i. e. too soon for the success of the fire, it was deferred, till dry weather again returned.

2. It was customary for those who had fallows to burn, to say, on seeing smokes from burning fallows, rising in different directions; "We must put fire to our fallow, for I see other folks are burning theirs; and we shall soon have rain; for it always rains soon after people begin to send up their smokes."

3. Fallows on fire, if extensive, did generally continue to burn till extinguished by showers of rain. Smaller fires, of course, would subside by exhausting the combustibles, before a change of weather. These storms or showers, as nearly as I can now say, were generally accompanied by lightning and thunder; and usually passed from the south west to the north east.

4. It frequently occurred that while some were burning their fallows, others were engaged in haying and harvesting. When hayers and harvesters observed the smokes of fallow fires, they expected rain soon, and secured their crops, or governed themselves accordingly.

5. Soon after the snows were off in the spring, I think generally the latter part of April, or the early part of May, fires sometimes, nay, often, broke out in the woods, raging furiously, sweeping in a few hours over thousands of acres of uncultivated wood land. These fires generally set towards the hills and mountains, climbing them much more rapidly than they would run on level or low ground. The air would set powerfully towards the hill tops, heaving up vast columns of smoke above them. Clouds soon after formed, and rain succeeded, to the joy of an anxious population, for these fires often did much damage.

6. Always, when the fires were large, the wind was observed to be towards the fire from every quarter. When the fires were raging on the mountains, and the wind was blowing powerfully towards them from the point on the side where I was, I recollect to have heard from the other side of the mountain that the wind set strongly towards the fire from that direction also, directly opposite in its course.

7. The storms which followed these fires in the woods, were generally the first in the season attended with thunder and lightning, to any considerable extent.

These facts are now written from memory. I believe they may be depended upon as substantially correct. At the time I observed them I had no idea of their connexion with meteorology. So far as I knew they were not understood by the inhabitants generally, as related to each other as proximate cause and effect. I can now refer to several scientific gentlemen in those counties, who would, I believe, confirm the foregoing facts, independent of any consultation with me, and without knowing that I have expressed these few simple facts on paper.

S. W. Fuller.

Philadelphia, October 28, 1838.

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214. I arrived on Cote Blanche, in St. Mary's, on the 3d of July last, and was astounded at the appearance of almost absolute sterility in every direction around me. Our manager informed me, that there had been no rain since the 1st of April. The corn was nearly destroyed, the late planting was literally dead to the top. The corn had improved very little for six weeks. Every thing wore the most gloomy and desolate appearance. On the 4th and 5th, several of the marsh Islands, lying in the Bay, twelve or fifteen miles distant from Cote Blanche, became ignited, by the electric fluid, and produced brilliant fires. The total absence of

dew, a fact, which I had never before witnessed, attracted my particular attention, — as indicating a state of the atmosphere still more alarming. The total destruction of the crop seemed inevitable. I watched, with much solicitude, the appearances and changes of the weather. The wind was extremely changeable, and showers appeared in the horizon at almost every point. About nine o'clock, on the morning of the 6th, I ordered fires to be set, at different places, to the marsh, contiguous to the Island. The fires continued to spread during the day, and at night presented a most beautiful scene.

On the morning of the 7th, a gentle breeze sprung up from the east, and blew steadily from that direction for several hours, carrying the fire and smoke from the Island. The smoke now presented the appearance of a vast and stupendous range of mountains, broken in abrupt and craggy peaks, gilded by the rays of the eastern sun, and reflecting all the colors of the rainbow. While the grandeur and magnificence of the scene was occupying the attention of myself and friend, at about eleven o'clock, an upper and directly opposite current of wind sprung up, driving the upper part of this vast volume of smoke directly back in the direction of the Island, wafting it over a space of atmosphere, perhaps two hundred or three hundred yards in height, so singularly transparent, as to attract our particular attention and remarks. This appearance continued for twenty or thirty minutes, when it commenced raining from this upper current of smoke through this extremely transparent atmosphere. In twenty minutes more, the rain became heavy and general over the whole Island, and continued for three hours, with the exception of two intervals of a few minutes each. From the whole appearance, I was so well satisfied that the fire exercised a powerful agency in producing the rain more speedily than we should other-have received it, that I expressed my intention of addressing Professor Espy on the subject. With great respect,

B. G. Tenney.

To Professor Espy.
22d March, 1840.

P. S. Other engagements have prevented my furnishing the above statement of facts at an earlier moment, as I intended. You will discover, from the manner, that they have now been thrown together in great haste.

With great respect, your obedient servant,

B. G. Tenney.

Philadelphia, 5 mo. 15, 1841.

Esteemed Friend,

215. At noon, on the twelfth day of the sixth month last, I set fire to a clearing of *six acres* in Wharton township, Potter county, Pennsylvania. It was what is generally called a clear day; the sun shone brightly, although there were a few broken clouds slowly moving towards the east.

After the fire was well under way, the wind began to blow towards it, increasing after the fire had arrived at its maximum.

The wind blew inwards from all sides, sometimes blowing the smoke in one direction, and sometimes in another. The clouds appeared to congregate and hover over the fire. After the fire became general and the wind strong, I saw no cloud cross over the fire, but could see the clear sky below the cloud.

Some of the neighbors were present, and appeared to be alarmed at the violence of the wind as it roared through the woods; it was more violent than I should have anticipated, had I not heard thee suggest that such would be the case.

Nevertheless, the rain did not come, and my friends began to smile; but we had not walked one mile northward towards our lodgings, (which was nearly two miles north of the clearing,) before it clouded over and began to rain a little, and at nine o'clock that evening, we had a gentle shower, sufficient to extinguish the fire, and then the rain ceased. Respectfully, I remain thy friend,

SAMUEL WEBB.

To Professor James P. Espy.

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216. The battle of Dresden, fought on the 26th and 27th of August: "On the 27th, the battle was renewed under torrents of rain, and amid a tempest of wind." [Scott's Napoleon, chap. 27, p. 190.

The battle of Ligny, fought on the 16th June: "After the battle the weather was dreadful, as the rain fell in torrents; but this so far favored the British, by rendering the ploughed fields impracticable for horse, so that their march was protected from the attacks of the French cavalry." [Scott's Nap. chap. 47, p. 323.

The tempest after the battle of Ligny, on the 16th, continued to rage with tropical violence till the morning of the 18th, and it continued gusty and stormy all day of 18th. p. 326.

The battle of Eylau, fought on the 8th February: "The action commenced at daybreak. Two strong columns of French advanced for the purpose of turning the right and storming the centre of the Russians. But they were repulsed in great disorder; the Russian infantry stood like stone ramparts and kept back the enemy with a heavy and well sustained fire from their artillery. About midday a heavy storm of snow commenced falling, which added to the obscurity caused by the smoke from the burning village of Serpallen." [Scott's Nap.

217. Capper, on Monsoons, page 171, says: At Madras,

on the 4th of June, 1776, morning fair, noon cloudy, in the the evening rain. N. B. More than two hundred pieces of cannon fired in salutes; quere, whether it occasioned the rain? This quere is particularly appropriate, as this is the dry season on the Coromandel coast, and it did not rain after this till the 30th of the month.

218. During the memorable siege of Valenciennes, by the allied army, in the year 1793, it rained violently every day soon after the heavy cannonading commenced. The allies employed two hundred heavy ordnance, and the besieged had above one hundred, and they were frequently all in action at one time. The rain, in the opinion of the combatants, was caused by the shaking of the clouds.

219. M. Arago mentions several cases to show that great fires and cannonading could not prevent thunder showers. One was the Hotel Montesson, at the end of Rue de Mont Blanc, which, on the first of July, 1810, was occupied by Prince Schwartzenberg. It was the evening of a *fête* given by the Austrian ambassador to Napoleon and the Empress Maria Louise. In the middle of the night an immense ball room was burned, and the vast columns of flame, over which the fire engines had little control, did not ward off a tremendous thunder storm which visited the immediate neighborhood. The lightnings followed with frightful rapidity, and illuminated the whole firmament; the thunder rolled without intermission; finally, torrents of rain descended, which distinguished the last embers of the fire.

And again M. Arago says, "I shall here repeat two facts which occur to my own memory, in the hope that they will lead to analogous statements. The 25th of August, 1806, being the day selected for the attack of the islet and fortress of Dannholm, near Stralsund, General Fririon, that he might harass and fatigue the Swedish garrison, ordered it to be cannonaded during the whole day. In spite of these powerful and continued discharges of artillery, a violent thunder storm visited the spot at nine o'clock in the evening. Again, it happened, oddly enough, that the English line-of-battle-ship, the Duke, of ninety guns, was struck with lightning in the year 1793, whilst it was cannonading one of the batteries of Martinico."

This distinguished philosopher does not express the belief that great fires favor the production of thunder showers, though he adduces facts which lean strongly to that side of the question.

[From the Academy of Natural Sciences, of Philadelphia, June, 1841.]

Professor Johnson drew the attention of the society to the atmospheric phenomena attendant on extensive conflagration; and stated, on the authority of Dr. H. King, of Washington city, that the burning of the prairies in Wisconsin and Missouri is frequently, and almost immediately, followed by rain. This observation had been confirmed to Dr. King by other observers; and in the western country it had become a popular impression that a prairie-fire was the forerunner of rain.

Dr. Coates had met with a statement in Nichols's History of Leicestershire, which bore on the same question; viz., that in the reign of one of the Stuarts, orders were sent to a sheriff of Staffordshire to discontinue the burning of the Ferns during the royal progress, because the operation was usually followed by rain.

Mr. Phillips adverted to the memorable hail storm which occurred immediately after the last great fire at Constantinople; the fact being fully authenticated by Mr. Walsh and Commodore Porter. That rain is common in South America after the burning of the Pampas, is familiar to meteorologists; and the attention of the members is especially solicited to this inquiry in order that a more extended series of facts may be collected and compared.

These are all the documents bearing on the subject of artificial rains which I have room to publish in this work. Let the reader judge whether the experiment ought not to be tried in a scientific manner, and whether there is any just ground to ridicule the proposition.

APPENDIX.

A.

Original Documents of the Great Liverpool Storm of the 6th and 7th of January, 1839. See Section VI.

[Shipping and Mercantile Gazette, 10th of January, 1839.]

At Arbroath, near Dundee, it blew extremely hard on the night of the 6th, from the S. and S. W. On the morning of the 7th, the barometer was lower than it was ever known before; one tenth lower than on the 28th of October last.

At Newport, W. of Ireland, lat. 54, on the night of the 6th it came on to blow a gale of wind from the W. N. W., and towards midnight became a perfect hurricane. At Belfast, at 10, P. M., of the 6th, we were visited with a dreadful hurricane from the W., which continued with unabated fury till 2, P. M., of the 7th. On the 5th, the wind was S. W., with frequent showers of snow.

At Dundee, the rain poured in torrents on the night of the 6th. On the 7th, the wind blew a gale from the N. W., and was so all night of the 6th. At 8, A. M., of the 7th, barom. 28.10, symp. 28.1, having fallen from 29.75 on the 6th. Still blowing hard at noon of the 7th, N. W.

Edinburgh, Tuesday, Jan. 8. On Friday and Saturday we were visited by a heavy fall of snow, more especially on Saturday, when it was accompanied with all the aggravations of piercing and violent winds, shifting to every point of the compass. Sunday brought with it a beautiful clear calm, with frost just sufficient to retain the snow in a solid form. In the evening, the wind became piercingly cold from the east, for a time, but suddenly changing to the opposite direction, a quick thaw commenced, accompanied with heavy rain; this continued during most of the night, and early yesterday morning it blew a perfect tornado, which continued, with little intermission, for many hours, during which it was with the utmost difficulty people could make their way through the streets. About noon, yesterday, it had become comparatively calm, and the snow in exposed situations had long before that time disappeared. Between Sunday night and yesterday morning the mercury in the barometer again underwent a remarkable depression, such as we had lately occasion to notice, having fallen in the instrument to one tenth of an inch below 28. Last night we had a return of smart frost. [Edinburgh Advertiser.

The Caledonian Mercury, of the 7th, (which I believe is published in Edinburgh,) says, "the snow continued to fall heavily the whole of Saturday, the 5th, and towards evening, lay to an average depth of twelve inches. Last night (that is, the 6th), the wind changed to S. E., with rain."

[Shipping Gazette, January 10.]

Stranaer, S .W. corner of Scotland, January 7. Last night, at midnight, it came on to blow a heavy gale at S. W., and at 4, this morning, it blew a perfect hurricane at W. N. W.

January 11. At Carnarvon, on the night of the 6th, it came on to blow a tremendous gale from the S. S. W. to N. W., which continued unabated almost till 4 o'clock on Tuesday morning.

At Whitby, north of York, the gale came on W. N. W., about 2 o'clock on the morning of the 7th, and continued a hurricane till after daylight.

At Londonderry, north of Ireland, the snow which fell on the 5th, began to thaw on the afternoon of the 6th; and about 11 o'clock that night, the wind shifted from S. W. to N. W., when it commenced to blow strong; and after that, the night was tremendous. On the 8th, wind west.

At Cove of Cork, on the morning of the 6th, wind E. P. M., wind W., storm and rain.

Lloyd's List, January 11. At Milford, S. W. of Wales, opposite Waterford, it blew a gale on the night of the 6th, from S. S. W. and S. W., but veerred at 2, A. M., to W. N. W., blowing a perfect hurricane.

At Bangor, west of Liverpool, it blew a very heavy gale on the night of the 6th from W. to W. S. W.

At Greenock, it blew a tremendous gale on the 7th, without intermission, from W. N. W., till evening.

At Westport, on the night of the 6th, it blew a terrific gale from S. W. to W. N. W.

January 12. At Strangford, it blew a hurricane on the night of the 6th, at W. S. W., and veered next morning to W. N. W.

At Shields, it blew a perfect hurricane from 1, A. M., of the 7th, till sun set, at S. W.

At Grimsby, near Hull, it blew a hurricane on the 7th, till 3, P. M., from W. by S. to W. by N., and continued on the 8th, W. N. W., a gale at intervals.

At Bowmore, Island of Islay, at 4, on the morning of the 7th, a severe gale commenced from S. W. and veered to N. W., the gale increasing.

January 15. The Guiana experienced on the 6th a dreadful hurricane, nine miles from Cape Clear, S. W. of Ireland.

At Portsoy, it blew a severe gale on the 7th from N. N. W.

At Montrose, on the evening of the 6th, and throughout the next day, it blew a hurricane from the W. N. W.

At Annan, on the 7th, it blew a severe gale from S. W. to N. W.

January 17. At Hamburgh, on the evening of the 8th, it blew a violent gale from S. W. to W. S. W., with tide rising 18 feet—part of the town under water.

George Innes' Journal, at Aberdeen.

Jan. 1839.	5	30.0	33.4	31.8	30.5	29.19	29.225	W.	Mostly clear; snow showers at night; fresh breeze.
	6	24.2	36.1	24.7	36.1	29.355	29.05	S. S. W.	Clear till sun set; cloudy at night; moderate breeze.
	7	35.4	38.2	38.3	32.6	27.645	28.79	N. N. W.	Heavy gale; hail, sleet, and rain; cloudy till sun set.
	8	29.3	31.3	31.2	28.3	28.915	29.26	N. W.	Stormy till past noon; mostly clear; snow at night.

"The sudden fall and extreme depression of the barometer, between last Sunday evening and Monday morning, was accompanied with an equally sudden change in the weather. Sunday had been calm, clear and frosty, but, towards night, it began to blow heavily from the N. W.; and, during the early hours of Monday, the wind had increased to a hurricane, accompanied with much rain. We believe that the barometer has never been observed to be so depressed as it was on this occasion. It fell 1.405 inch during the night; and on Monday, at 8, A. M., it indicated 27.645 inches!

[Hull Advertiser of January 11, 1839.]

The storm came on at Whitby about 2, A. M., of 7th, with the wind at S. S. W., which kept traversing till it was due west, when it was stationary. At about 4, it was highest.

At Boston it commenced blowing very hard, about 5, A. M., of 7, from the westward. At 6, it blew a complete hurricane.

[Hull Gazette, of 12th.]

At Newcastle, it commenced about 1, A. M., of 7, from S. W., and continued with unabated fury throughout the day. The wind veering round to the northward about mid day, when it was W. N. W.

[Liverpool Storm of 6th and 7th January, 1839.]

Times of Jan. 16. At Cape Clear, a most tremendous hurricane on the 6th.

Times of Jan. 13. Throughout the early part of Monday, the 7th, the wind was a strong breeze from the S. W. with squalls at London.

Morning Chronicle, of 22d. On the 6th, a dreadful gale from West, off Fern Islands.

Chronicle of 16th. The Amanda was in a hurricane on the 6th, in longitude 16°, coming from Newfoundland to Cork.

Times of Jan. 13th. The wind during the day at Liverpool had been about S. S. E., and rather strong. About 10, P. M., it died away, and the atmosphere became mild and warm. In a few minutes it began to blow with alarming gusts from the S. W. and W. S. W.

At Sunderland, a few miles south of Newcastle, the gale came on early on the morning of 7th, wind about S. S. E., and continued to blow very heavy during the whole of the day, changing S. W. and W.

At Glasgow, there was a continued storm of tremendous character from Thursday the 3d. On Thursday and Friday there was heavy rain, accompanied with high wind. On Friday and Saturday snow, very heavy on Saturday night. During the day on Sunday, there was an apparent intermission; but by 10, at night, the wind became fearful and brought torrents of rain. The barometer on Sunday morning, was hovering about "*rain.*" In the afternoon it suddenly sunk to "*much rain*" and "*stormy,*" and at a quarter before four, on the morning of the 8th, it stood at "*set fair.*"

At Whitehaven, N. W. of England. In the afternoon and evening of Sunday the 6th, the wind blew softly from S. W.; but during the night it shifted to N. N. W., and before 2 o'clock, it began to blow a perfect hurricane, and continued till morning.

At Dublin the tempest, such as the oldest inhabitants cannot remember, commenced at 10 o'clock, P. M., of the 6th, from S. S. E., and varied in the course of the night frequently from that to S. S. W. Its fury abated about six in the morning.

At London, throughout the early part of Monday the 7th, there was a strong breeze from S. W. with squalls. About 3, P. M., there was hail and rain, and as night advanced the wind increased to a gale, with heavy squalls.

The storm of Sunday evening was productive of much mischief in the vicinity of the metropolis.

At Chester, little south of Liverpool, the hurricane was terrific on Monday night from 12 till 2, and a fearful continuance of the gale even after that hour.

Narrative — second edition — page 95. At Loughrea, near the middle of west coast of Ireland, at 6, A. M., of 7th, the wind changed from N. W. to W.

[Leeds. Mr. Denny's Journal.]

Jan. 7th,	A. M., at	9½	wind W. S. W.	Barom. min. 28.375
	"	10	W. N. W.	28.490
	"	11½	W. N. W.	28.500
	"	12	W.	28.525
	P. M.,	2¼	W.	38.555
	"	3¼	W.	28.575
	"	4½	W.	28.610
	"	7	W. N. W.	28.710
	"	10	W.	29.010

[Belfast News Letter of 11th Jan. 1839.]

At Londonderry there had been much snow for two days, but no appearance of storm. About 12, on the night of the 6th, the storm broke out, the wind being then south eastwardly, from which point it gradually veered to S. W. It did not subside till 6 next morning.

At Loughrea, houses fell about 11, P. M., from the violence of the hurricane, and at about 6, A. M., the wind changed from N. W. to W.

[Dublin Evening Herald of Jan. 10.]

The town of Birr, near centre, little south, on the night of 6th, and morning of 7th, was visited by the most awful tempest that has perhaps ever occurred in Ireland. The wind blew during the hurricane S. W. by W., and the barometer, so early as seven o'clock in the evening, indicated the approaching convulsion. While I was at dinner my attention was drawn to this instrument and I found it had fallen to 28.65, from

29.1 inches, at which it had stood in the middle of the day. As the wind sprung up, it fell to 28.5, which was the lowest point observed during the tempest.

Drogheda Journal, Jan. 8, quotes from the Newry Telegraph, and says, on Sunday night, at Newry, about 11 o'clock, the wind which previously had been blowing hard from the N. E. rose suddenly to a pitch of fury rarely paralleled in this latitude. It continued to increase in violence during the whole night, but abated in the morning.

[Drogheda Journal, of Jan. 8.]

East Coast of Ireland. Never in the memory of man, has this town been visited by such an awful storm as that of Monday morning.

About 11 o'clock on the previous night, the wind rose from the S. E. with a degree of violence as terrific as unprecedented, and continued to blow a perfect hurricane until an early hour next morning.

The Drogheda Journal of 12th January, 1839, says: On Sunday night the 6th, the city and county of Dublin, were visited by one of the most destructive storms within our remembrance. The weather during the whole day, excepting only from 3 till 5 P. M. was very unfavorable, misty and cold.

About half past 5, rain commenced, with a smart gale from the south and S. W., which increased at intervals until half past 11, P. M., when it blew a complete hurricane.

[Liverpool Standard, of 15th January, 1839.]

At Cove, near Cork, during the whole of the night of the 6th, it blew a violent gale at W. S. W., having commenced at 9, and terminated about 4, A. M., of 7th.

At Waterford, the wind set in a strong gale from the W. S. W. at an early part of the evening, and gradually increased to an unmitigated hurricane.

At Wexford, south east corner of Ireland, we were visited, on the night of the 6th, with one of the most violent hurricanes from the S. W. ever remembered by the oldest inhabitant.

At Derry, a tempest seldom, if ever surpassed, commenced at 11 o'clock, P. M. on the 6th, with the wind about S. E., from which it afterwards changed to S. W. It was accompanied at intervals and at its most violent periods, by torrents of rain, and continued with little abatement till about 6, A. M., on Monday.

Londonderry Sentinel, of 12th, says, a violent westerly wind began to blow at Belfast, about 11, P. M., of 6th, which increased in about an hour to a complete tornado. The beginning of the night was comparatively calm, a considerable snow having fallen through the day of the 6th.

[Shipping and Merc Gazette, of January 12th, 1839.]

At Bowmore, Island of Islay. January 7, a very severe gale commenced here this morning, about 4 o'clock from S. W., and then veered to N. W., still increasing.

Ballina, W. N. W., coast of Ireland, we had a tremendous gale of wind here from the westward, on the night of the 6th January, 1839.

At Largs, near Glasgow, on the night of 6th, it blew a complete hurricane from S. W. On the 7th at 6, A. M., the sloop Industrious Helen, came on shore here, and about 6, P. M., the wind N. and moderated.

[The Meteorological Journal of J. C. Sewell, of Sheffield, for 6th January, 1839.

	Barom.	Wind.	Weather.
4 A. M.,	28.92	S. S. E.	Snow.
12 noon,	28.85	S.	Rain.
4 P. M.,	28.65	E. S. E.	Snow.

[Shipping and Merc. Gazette, of 11th January, 1839.]

At Strangford, N. E. of Ireland, a most awful hurricane commenced on the night of the 6th, at 12 from the W. S. W., and shifted on the morning of 7th, to W. N. W.

At Limerick, a very heavy gale of wind came on from the westward, about 9, P. M., of the 6th, and increased till midnight, when it blew as tremendous a hurricane as ever recollected.

At Douglas, Isle of Man, on the night of the 7th, the harbor which is usually dry at low water, had from 6 to 7 feet water in it at the hour of low water.

[Shipping and Merc. Gazette, of 12th.]

Montrose, January 8th. The Marmion from Newcastle, while taking the harbor last night, with strong northerly wind, missed stays and went ashore on the rocks.

Campbeltown, S. W of Scotland, on the night of the 6th, it blew a fearful gale from S. W. to N. W.

At Portsoy, between Bamff and Fochabers, E. of Inverness, on the 7th, blowing a gale from N. N. W.

Lloyd's List, January 8th. It blew a dreadful gale W. S. W. at Buxham, on the night of 6th. At Plymouth it blew very heavy on night of 6th, S. W.

At Lowestoffe, east coast, it blew a heavy gale S. W. all night of 6th.

Do. of 9th. At Sheerness, mouth of Thames, it blew very strong from S. S. E. to N. N. W. from 6th to 8th.

At Falmouth, in Cornwall, it blew a heavy gale, with violent squalls from W. all night of 6th.

At Swansea, on Bristol Channel, on the whole of the night of the 6th it blew a strong gale, commencing S. S. E., and gradually veering to W. S. W., and at two in the morning it blew a hurricane at W. N. W., and continued till 6, A. M., when it moderated.

At Port Talbot the wind flew round to N. W. at one o'clock in the morning, and blew a perfect hurricane.

At Thwaite, near London, by O. Whistlecraft.

January 6. Barometer, 29.79 to 29.40. Frost. Hazy, A. M. Overcast, P. M., snow and rain, and, in the evening, wind increased. Temperature, 30° to 35°. Wind S. W., gentle in the morning. S. S. W., fresh at noon; and S. S. E., strong at evening. From 10 till 12, night, it gradually veered from S. S. E. to S. and S. W., continuing very strong. Barometer rapidly falling to 28.98. Rain at times.

January 7. Barometer 28.98 to 29.14. Tremendous hurricane from W. S. W., most violent here from 3, A. M. till 6, A. M., fine with flying scuds and cumuli, violence gradually abating from 6, A. M. till noon; but still strong, then cumuli and sun. Temperature, 33° to 44°. At 8, P. M. a gale at W. with snow; the wind now squally; and on the whole as strong as at noon, but far less violent than in the morning. Buildings and trees are thrown down in many places.

January 8. Gale at N. W., and snow storm, 7, A. M. Strong gales all day; chiefly clear and frosty. Temperature 29° to 34°. Much lightning, evening, in the east horizon. Wind now W., only brisk. Barometer, 29.42 to 29.61.

Journal of James Vidgen, of New Romney, S. E. corner of England.

Date, 1839.	A. M. Barometer.		A. M. Ther.		A. M. Winds.		Barometer.		Therm.		Winds.	
Jan.	8o'cl.	noon	8	N.	8	noon.	3 P M	8 P M	3 P M	8 P M	3 P M	8 P M
Sun.6	29.63	29.62	41	42	N W	Wstly.	29.61	29.24	44	44	N W	S E
Mon7	29.05	29.00	42	47	W bN	W N W	29.00	29.04	47	46	W N W	W N W

Remarks, &c.

Sunday, January 6th. A. M. Light winds, with rain. 8, Same weather. Noon, Strong Breezes, and squally, W. P. M. 3, Strong breezes, and squally. 8, Same to midnight. Strong gales, with heavy squalls of wind and rain.

Monday, January 7th. A. M. Strong gales, and squally, with rain. 8, Strong breezes, and cloudy. Noon, Same weather. P. M. Strong breezes, and cloudy, W. 3, Strong breezes, with heavy squalls of wind and rain. 8, Strong breezes, and fine. Midnight, same weather.

[Extract from the log of ship Everthorpe, from St. Petersburg towards Liverpool, off the Skerries of Clestron. Civil reckoning.]

January 6, 1839. This day begins with strong winds, W. by N. Middle part, light winds, variable, with rain. Latter part, fresh breeze, N. W. This log ends with midnight, at 8, A. M. of 7th. Calm, at midnight dreadful gale, N. E., and at 3.30, A. M., perfect hurricane, N. W.

[Shipping and Merc. Gazette, of January 8, 1839.]

At Southwald, 104 N. E. of London. The sloop Young Susannah came on shore at 8, P. M. of the 6th, in a gale from S. to E.

At Liverpool the wind, which had been S. E., suddenly veered about 11 o'clock to S. W., and afterwards to W., blowing a complete hurricane.

At Longhope, Orkney, on the 30th December, it blew a perfect storm the whole day, N. W., and from 1 h. 30 to 2 h. 30, a complete hurricane. At the same time, at Montrose, there was a hurricane from the S.

January 9. At Llanelly wind strong S. W. on 7th.

At Bridlington, York, January 7. Last night the wind got to S. E. blowing a gale, and fell moderate at midnight, but about 3 this morning the awful scene commenced, the wind at W.

At Seaham, on 6th, wind N. N. W., with snow.

At Sunderland, near New Castle, east coast, January 7. This day we had a heavy gale, with the wind from S. S. E. to S. W. and W.

At Dundalk, between Dublin and Belfast, on 6th, wind S. W. Rain.

At Inverness, on 5th, a heavy fall of snow.

At Youghal, E. of Cork, January 5. The weather from the 30th ult. to the 4th inst. may be classed as much alike each day, damp, cloudy, and foggy, with light rain at times, wind W. S. W.

At Londonderry, January 5, wind W. with strong gales, and a heavy fall of snow.

At Kingstown, the morning of 6th was fine, wind at S. or S. S. E.

At Bridlington, on night of 5th, wind hard N. W.

At Workington, Solway Firth, January 7. It blew last night from the S., and at this morning it veered to the W., blowing a complete hurricane.

My Dear Sir, — The following are such particulars as I can now give (unfortunately not having taken notes at the time,) of the hurricane of January, 1839.

The barometer on Saturday evening the 5th January, stood at about 31½ inches, with moderate weather. On Sunday morning the 6th January, at about 8, A. M., a steady breeze, but moderate, barometer having fallen to about 29 inches since the preceding night. During the morning, a little rain began to fall, the wind gradually rose until afternoon; from 3 to 5, P. M., much rain; the wind blowing very hard from W. S. W., which continued until 7 to 8 o'clock; wind then changed, I think, to S. E. 9, P. M., more wind from about S.; 10h., a complete gale from W., which kept increasing until ½ past 11, when, I believe, it blew from S. W. or W. S. W.; from this time, until 3 o'clock of Monday morning, it was at its height, when the wind remained about W.; from this time, the wind gradually subsided.

The atmosphere, during the gale, became charged with a green saline vapor, which was carried a considerable distance inland, having rendered the water kept for private use, so salt as to be unfit for culinary purposes. Such was the violence of the storm, that in exposed situations, persons could not, during the gusts, walk against it, and if going before it, had great difficulty in keeping their feet. I was, myself, twice blown in this way a considerable distance; looking to windward was also impossible, except when the wind lulled. At these intervals, the following squall might be distinctly seen, as a white mist rolling along the water.

It appears the greatest force of this storm was felt between the counties of Kerry and Galway, on the west of Ireland. If I can give any further information, I shall be most happy.

Believe me, dear Sir, yours, most truly,

William Monday.

Kilrush, near the mouth of the Shannon, Ireland.

[Leed's Intelligencer of 12th January, 1839.]

Sunday the 6th, there was a slight fall of snow in the morning; and during the P. M., there were occasional showers of rain, the wind being gentle, and tolerably steady from S. S. E. Up to 8, P. M., there was no striking depression of the barometer, which stood, during the day, at about changeable, but the mercury descended more than ½ an inch between 9 and 12. Soon after 12, the wind began to veer about from the S. E. to S. W., blowing in gusts, which rapidly increased in violence, till about 2½, when it blew a violent gale — blowing down chimneys, &c. Salt was found abundantly, encrusted on the trees, both at Leeds and Manchester.

Whitby, Eastern coast of England, by Henry Belcher. Sunday 6th, barometer, 29.70, A. M., thermometer, 25°, clear bright frost, — P. M., a thaw, barometer falling to 29.30. All night rapid thaw, and *high wind S. by E.*, and the barometer falling rapidly, (observations made at ½ past 10, P. M.) During the night, the wind became more southerly, and more violent, and towards morning, blew the most dreadful gale from the S. by W., experienced at Whitby for *many* years, (old people say fifty.) The barometer fell to 28.40, at A. M., on the 7th, at which time, the storm was at its height. The barometer then began to rise, and by 10 o'clock, stood at 28.60, the wind during the day, continued gradually veering to the north west, with a return of frost. On the morning of the 8th, the barometer had risen to 29.40, the wind being W. N. W., and blowing fresh.

Berwick, East coast of England, by James Forster. The wind was W. N. W. in the morning of 6th, strong; at 10, it changed to W. S. W., fresh. At 3, P. M., there was a calm. At 5, P. M., it was S. S. E., fresh, and continued increasing in that direction, till 10, when it changed to S. S. W., and continued S. S. W., not very violent, till 7, A. M., of 7th, when it got round to W. N. W., a violent gale, and continued W. N. W., and W. all day, very violent.

[Remarks, on board Ship Scotland, 1839.]

Saturday, 5th January, Sea Account, P. M. Moderating, made sail as occasion required through the night, wind and rain squalls from west northerly. At 8, A. M., wind veers to W. S. W , and S. W., tacked to N. W. At 11h. 30, A. M., blowing a gale from W. S. W., with rain, reduced down to close reef fore and main topsails. Lat. 49° 18′, long. 29° 50′, W.

Sunday, 6th January, Sea Account, P. M. Heavy sea, ship laboring very hard, wind west, and continues through the night. At 8½, A. M., wind changes to about N. W. by N., and blows a complete hurricane; wore ship to W. S. W., water making a clean breach over the ship. Such a scene cannot be described, and ends the same lat. 49° 48′, long. 30° 00′.

Monday, 7th January, Sea Account, P. M. The first four hours, a continuance of the same, then moderates, and through the night, moderate and squally, making sail as required, ends squally and baffling, from N. W. Lat. 47° 48′, long. 30° 11′.

William Robinson.

Liverpool, July 16th, 1840.

[The Shipping and Mercantile Gazette, of January 8th.]

At Aberavon, Wales, the wind shifted from S. S. W. to S. S. E. At 10, A. M. of 6th, blowing hard, with rain, very dark, barometer 29.22, having been on the 5th, 29.65.

At Deal, it blew very hard at night of 6th, and also on 7th, W. S. W., with squalls of rain.

At Ramsgate, East of London. 7th. Throughout the whole of last night and to day, it has blown hard from S. S. E. to W. At 8, P. M., W. N. W., more moderate.

Scowrie, Scotland, from George Ross. Upon the 6th and 7th, it blew a complete hurricane in this quarter, with frequent showers of hail. Upon the 6th, the wind blew from S. W., in the evening, it veered round to N. W., and continued to blow from N. W., until 12, at night.

I have further to add, that for many days before the 6th and 7th of January, it was a continuation of stormy weather, the wind constantly blowing from S. W. and W., and sometimes N. W.

Journal kept on board H. M. Packet, the Doterel. From Kingstown, the 6th of January, 1839, to Liverpool.

Hours.	Winds.	Weather.	Speed of Engine.	Rate of Vessel.	Sunday, 6th January, 1839.
8	S. W.	Fresh gales and cloudy.			8 h. 44, P. M., received the Mail at Kingstown quay, and proceeded — set single reefed fore and mainsails.
10	"	Heavy gales and squally with thick rain.			
12	"	Very hard gales and squally, with rain.			9 h. 45, hard gale, close reefed fore and mainsails.
					Monday, 7th.
2	W. S. W.	Quite a hurricane, with rain.			2 h. A. M., quite a hurricane, with a tremendous sea, considering it unsafe to run on a lee-shore, took in the sails, and rounded the vessel too, with her head to S. S. W.
4	"				
6	W.N.W.				3 h. 45, wore ship and kept her head to the N. W.
8	"	Very hard gale, and squally.			6 h. shipped a heavy sea, which washed away the starboard round house and part of starboard bulwarks. 8 h. 30, made the Head, bearing E. S. E., about three miles — bore up for the harbor. 9 h. 15, arrived at Holyhead, and delivered the Mail.

Viscount Adare's Journal, near Limerick, S. W. of Ireland.

1839.	hour.	Bar.	Wind	force.	
Jan. 5.	8, P. M.	29 60	N. W.	2	Snow last night, and long, hail and rain showers to-day.
6,	9, A. M.	308	S. S. E.	1	Cumulostrati and nimbi. a drizzly rain, towards evening clouds moved fast from W.S.W. Wind began about 4, P. M. and blew from 11 till about 4 or 5, in the morning a tremendous hurricane, particularly remarkable for the furious squalls. Sky quite clear at 11 and 12.
	3, P. M.	130	W. S. W.	1	
	6½, "	25.930	W. S. W.	3.4	
	9, "	724		4.5	
	11, "	642		5	
	12, "			6	
D. 7,	8, A. M.	29.030	W. N. W.		At 8, this morning, wind down to 2 or 3, but tremendous squalls, with snow and hail storms, which gradually diminished towards evening.
	9½, "	090			
	4½, P. M.	250	W. N. W.		
	11, "	380			

I generally mark the wind by figures, from 0 to 5. The last being a regular full gale.

[The Hull Times of January 18, 1839.]

There was a tremendous storm at Hamburg, on the night of January 8, 1839.

Extract of a letter from the second mate of the Sally, that sailed from Kilrush, dated January 6. We experienced strong gales, and heavy seas, and had proceeded as far as 21° west long., being then under close reefed top sails, and reefed foresail. At 5, P. M., the night on a sudden became extremely dark, accompanied with a complete hurricane, tearing away the foretopsail, and splitting the foresail all to ribbons.

[Orkney. Furnished by Graham Hutchison, Esq. Glasgow.]

1839	Bar. 10 A M	Dir. of wd.	Force of wd. at 10 o'clock, P. M.	Character of weather.	Bar. 10 P M	Dir. of W'd.	Force of wd. at 10 o'clock, P. M.	Character of weather.
Jan 5,	28.9	S W	Moderate.	Snow showers.	29.	N W	Strong.	Snow drift.
6,	29.2	S W	do.	do.	28.8	S E	do.	Snow showers.
7,	27.7	N	do.	Cloudy.	28.4	W	Very strong.	*Rain*. Frost at night.
8,	28.8	S W	Very strong	Snow showers.	29.1	N W	Strong.	Hail showers.

[Extracted from Greenock letter received at Glasgow Exchange. Furnished by G. Hutchison.]

January 5,	W. S. W.	Strong gales with snow and hail.
6,	W. S. W. and W. N. W.	Heavy gales with snow and rain.
7,	W. N. W.	Heavy gales and heavy weather with rain.
8,	W. N. W.	Moderate breezes with snow.

[Extracted from Meteorological Journal, for January, 1839, kept at the apartments of the Royal Society, London.]

	Barometer.	Dir. of wd. at 9, A. M.	Character of Weather.
January 5,	29.682	S.	Fine, clouds and wind throughout the day, evening fine and starlight.
6,	29.718	S.	A. M. overcast; light wind; rain early. P. M., overcast; snow and rain; evening, heavy rain with high wind.
7,	29.072	S.	A. M., fine, light clouds, very high wind, as also throughout the night. P. M., hail and rain, light winds; evening fine and starlight.
8,	29.538	W.	A. M., fine and cloudless, light wind. P. M., dark heavy clouds, brisk wind.

[Extracted from Lloyd's List, London.]

Wind at noon.	Memoranda.
Jan. 5, S. W.	Holyhead, 7th Jan. It has blown throughout last night and this morning a tremendous gale from W. S. W. to W. N. W. by N.
6, ——	Chester, 7th Jan. About midnight, it commenced to blow a tremendous gale at south, but flew to W. N. W. a complete hurricane; is now moderating.
7, W. S. W.	
8, N. W.	Liverpool, 8th Jan. The gale continued with but little abatement till about 3 o'clock this afternoon; is now nearly calm.

[Extracted from the Register kept by Mr. Thomson, at the garden of the Horticultural Society, at Chiswick, near London.]

	Barometer. Max.	Min.	Dir. of wind at 1, P. M.	Character of Weather.
Jan. 6,	29.735	29.147	S. S. E.	Overcast; sleet; rain at night with wind increasing to a hurricane.
7,	29.343	29.096	W.	Boisterous.
8,	29.592	29.526	W.	Clear; slight snow.

[Extracted from Register kept at Applegarth Manse, Dumfries-shire, by Mr. Dunbar.]

	Barometer. 9, A. M.	8½, P. M.	Wind.	Character of Weather.
Jan. 6,	29.55	28.99	S. W.	Frost and snow; rain, P. M.
7,	28.26	29.00	W. N. W.	Fearful storm; rain and sleet.
8,	29.30	29.40	W. N. W.	More calm; more snow.

[Glasgow. Furnished by Graham Hutchison, Esq.]

Date.	Bar. at 10 A. M.	Direction of wind at 10, A. M.	Force of wind at 10, A. M.	Character of Weather.
1	29.9	W.	Very Strong.	Showery.
2	29.8	W. N. W.	Moderate.	A little rain.
3	29.4	S. W.	Do.	Do.
4	29.1	W.	Strong early A. M.	Snow or sleet showers.
5	29.2	W. S. W.	Moderate.	Much snow.
6	29.3	W. S. W.	Light wind.	Frosty morning, rainy evening.
7	28.1	W. S. W. or W.*	V. stg. early A. M.	A lit. rn. hur. and light. ear. A. M. clear aft. with lt. wind fr. N. W.
8	29.2	W. N. W.	V. stg. early A. M.	A little snow; clear evening.
9	29.7	W. N. W.	Light wind.	Dry, frosty and clear.

* S. E. wind, evening; bar. 27.9, at 7, A. M.

OBSERVATIONS MADE AT SEVERAL OF THE NORTHERN LIGHTHOUSES, DURING THE STORM OF 7TH JANUARY, 1839, COMMUNICATED TO THE ROYAL SOCIETY BY ROBERT STEVENSON, CIVIL ENGINEER.

Name of Lighthouse.	N. Lat.		W. Long.		Lowest state of Barom.	Time when lowest state occurred.	Time the wind was strongest.	Direction of the wind.	Variation of wind during the Storm.	Time when lull or abatement was observed.	Storm commenced.	Storm ended.
	deg.	m.	deg.	m.								
Inchkeith.	56	2	3	8	27.50	5, a. m., 7th	12, m., 7th	W.	S. W. to N.	None observed.	1, a. m., 7th.	4, p. m., 7th.
Isle of May.	56	11	2	33	27.64	9, " "	1, a. m., 7th	S. W. to W.	S.W. to W.and N.W.	None observed.	6, p. m., 6th.	morn. of 8th.
Girdleness.	57	8	2	3	27.72	9, " "	1, p. m. "	N. W.	S. to N. W. and N.	9, a. m., 7th.	9, p. m., 6th.	11, a. m., 8th.
Buchanness.	57	28	1	46	27.40	6, " "	5, p. m., and 5, a. m., 8th	N. W.	S. to N. W.	9, p. m., till 12, 7th.	10, a. m., 7th.	12, m., 8th.
Kinnaird Head	57	42	2	1	27.44	8.30, " "	4, p. m., 7th, and 5, a. m., 8th	N. N. W.	to N.	12, night, 7th.	1, p. m., 7th.	morn. of 9th.
Tarbetness.	57	51	3	48	27.53	4, " "	12, m., 7th, 6.30, a. m., 8th	N. N. W.	No variation.	None observed.	10.30, a.m., 7th.	8.30, a. m., 8th.
Pentland Skerries.	58	41	2	55	27.60	4, " "	6 to 8, p. m., 7th 3 to 6, a. m., 8th	N. W.	No variation.	None observed.	12, m., 7th.	2, p. m., 8th.
Start Point.	59	17	2	23	27.55	9, " "		N. W.	S. to N. W.	5 to 6, p. m., 6th, 8, a.m., till 11½, 7th	3, p. m., 6th.	11.30, a.m., 8th.
Sumburgh Head.	59	51	1	16	27.25	2, p. m. "	3 and 6, a. m., & 3, p. m., 8th	N.	S.W. to N.W. and N.	9, a.m., till 1, p.m., 8th	2, p. m., 7th.	8, a. m., 9th.
Dunnet Head.	58	40	3	21	27.35	7, a. m. "	3, a. m., 8th	W.	N. N. W.	10, p. m., 7th.	12, m., 7th.	daylight of 9th.
Cape Wrath.	58	37	5	0	27.32	12, night, 6th	2 to 6, p. m., 7th		W.N.W. to N.N.W.	Frequent.	10, a. m., 7th.	9, p. m., 7th.
Island Glass.	57	52	6	33	27.76	5, p. m., 6th	6, a. m., 7th	W.	W. to N. W.	None observed.	11, p. m., 6th.	11, a. m., 7th.
Barra Head.	56	48	7	38	27.40	9, p. m., 6th	1 to 2, p. m., 6th	S. S. E.	N. W.	3, p. m., 6th.	morn. of 6th.	aftern'n of 7th.
Lismore.	56	30	5	38	27.55	4, a. m., 7th	9.30, a. m., 7th	N. W.	to N.	None observed.	8, a. m., 7th.	evening of 8th.
Rhins of Islay.	55	41	6	29	27.44	3, " "	6, a. m., 7th	N. W.	to W. and N.W.	4.30, a. m., 7th.	5.30, a.m., 7th.	12, m., 7th.
Mull of Kintyre.	55	19	5	49	not gvn.	4, " "	6, a. m., 7th	N. W.	S. to N. W.	None observed.	11, p. m., 6th.	9, a. m., 7th.
Pladda.	55	26	5	7	27.56	4, p. m.* "	6 to 8, p. m., 7th	S.	S. to W.	3.30, a. m., 7th.	3, a. m., 7th.	2, a. m., 8th.
Corsewall.	55	1	5	9	28.15	5, a. m. "	5, a. m., till day-break 7th	S. W. to W.	W. to N. W.	None observed.	12, night, 6th.	2, p. m., 7th.
Portpatrick.					28.15	3, a. m. "	3, a. m., to 8, a. m. 7th	S. W.	S. W. to W. N. W.	None observed.	11.30, p.m., 6th.	5, p. m., 7th.
Mull of Galloway.	54	38	4	51	27.44	1.45, a. m., 7th	1, a. m., 7th	S. W.	S. to S. W. and N. W.	None observed.	12.30, a.m., 7th.	3, a. m, 7th.
Point of Ayre.	54	25	4	22	27.89	4, a. m., 7th	3.30, a. m., 7th	W.	W. to N. W.	2 hours at daylight.	1.15, a.m., 7th.	3, p. m., 7th.
Calf of Man low.	54	3	4	49	27.50	2.30, a. m., 7th	6.45, a. m., 7th	N. W.	S. S. W. to N. W.	None observed.	12.30, a.m., 7th.	
Bell Rock.	56	26	2	23	27.55	6, a. m., 7th	10, a.m. to 1, p.m. 7th	S. to S. S.W.	W. and N. W.	7 to 8, a. m., 7th.	evening of 6th.	forenoon of 8th

* a. m. ?

Observations made at the Northern Lighthouses during the Storm of January 7th, 1839.

At Lismore, at four, A. M., of 7th, wind gentle, S. W.; barometer lowest. At eight, wind, N. W., tremendous gale,

At Isle of Glass, the storm began at about 11, P. M. of 6th, and varied with each shower, from W. to N. W.

At Dunnet Head, snow all day on the 5th, and at 10, P. M., of the 6th, it began to snow again and rain till about 1, A. M., when it faired up, and became quiet. At 7, A. M., of 7th, barometer 27.35, and stood so till evening, when it began to rise at 9, P. M., 27.95. At 7, A. M. of 7th, light air, S. E., and cloudy. At 8, a calm, at 9, light breeze N., or N. N. W., but soon increased to a gale, and by 12, noon, it blew a heavy gale, and veered N. W., continuing the same till about 10, P. M., when it abated a little. About 12, at night, barometer 27.98, but soon began to fall again, and at 3, A. M., of 8th, was 27.65, and at that time wind veered about W., a complete hurricane, with thick snow, continuing till day light. Then abated a little, but blew a gale all the 8th, and most of the 9th, N. W.

At Sumburghead, snow and sleet at 2, P. M., of 7th. At 9, heavy showers of snow and hail; barometer 27.84.

At Start Point, wind S. W., on 6th, with hail at times, till about two, P. M., it blew a gale, and by three tremendous, but died away in the night. And at 8, A. M., of 7th, nearly calm. It continued calm till between 11 and 12, when it began to blow N. W., and continued a most tremendous gale for 24 hours.

At Pentland Skerries, the rain cleared off at 2, A. M., of 7th, very warm, 48°, at 4, A. M.; at 9, A. M., not a breath of air; smoke going straight up. At eleven, A. M., wind went round to N. W., and at noon, the storm was strong. Snow. Between 6 and 8, P. M., storm most violent, but still worse on the 8th, at 3 to 6, A. M.

At Kinnard Head, not much wind till 1, P. M. of 7th, W. N. W., violent at 3 and 4, continuing till midnight; then cleared and abated, but increased again till 5 or 6, A. M., when it was as strong as before; then abated a little, but blew a gale till the evening of the 9th.

At the Calf of Man, the wind began to shift from S. S. W., at 9, P. M., and at 5, A. M., it had got to W.; it was a gradual shifting; it was S. E., on the 6th, hour not mentioned.

At Cape Wrath, the wind is marked N. W., on the 6th, gale and snow; on the 7th, N. W. storm and snow.

B.

Documents of the Storm of the 17*th of August*, 1840.

[See Article 173.]

Memorandum of the direction of the wind at Leeds, during the 16th, 17th, and 18th of August, 1840. By James S. Marshall.

16th. Wind S. W., brisk breeze; fine day; a number of cumuli of considerable height. About half past 4, P. M., whilst observing the cumuli, saw a S. E. current set in, bringing light fleecy cirro-strati with it, above the current carrying the cumuli. There was a higher current about S. W., carrying cirro-cumuli above the S. E. current. Towards evening. the sky was generally overcast; wind still S. W., and diminishing in force.

17th. At 8, A. M., wind S. E. or S. S. E., strong, with rain. Heavy clouds, at a moderate height, were at this time moving from the S. W. About 1, P. M., or rather sooner, wind changed to S. S. W. and S. W., and increased in force; clouds above moving from W. Wind gradually veered to W., and about 11, P. M., due W. and at its greatest strength; clouds moving from N. W.

18th. In the morning, wind N. W., strong, but less so than the preceding evening; veered during the day to N. N. W. or nearly N.; sky during the day, generally clear.

Barometer at Philosophical Hall, supposed about 90 *to* 100 *feet above the sea.*

	10, A. M.	10, P. M.
16th,	29.835	29.060
17th,	28.700	28.725
18th,	29,180	29.415

I wrote down memoranda of the above at the time, which, being mislaid, the above is written from memory.

James S. Marshall.

[Furnished by Dr. Harwood, *Sheffield*.]

Mr. Heppenstall says the wind began on the 16th, early, blowing from the S. S. by W., and continued all day, varying toward the S.; and so till morning, when it varied to the S. S. by E., and continued so most of the day. On the morning of the 18th, it had got round to the E., and subsided about noon. It was the strongest about noon of the 17th. It rained heavily most of the time.

[Hyde, near Manchester, by D. Green.]

	Barometer.			Thermometer in the shade.			Wind.			Weather.
	9 A.M.	12 Noon.	4 P M.	9 A.M.	12 Noon.	4 P.M.	A.M.	Noon.	P.M.	
15th	29 50	29 50	29.60	57	53	58	N.W.	W.	N.W.	Fresh breeze.
16th	29.60	29·60	29 50	55	62	57	S. W.	S.W	S. W.	Moderate gale.
17th	28.7	28.7	28.3	55	48	43	S. W.	W.	W.	Rain, snow, hail.

Meteorological Register, for the Port of Liverpool.

16th,	Morn.	W. N. W.	Bar. 29.98	Ther. 57	Moderate breeze and cloudy.
"	Even.	W. S. W.	29.98	65½	Moderate breeze and cloudy.
17th,	Morn.	S. S. W.	29.70	58	Fresh breeze and cloudy.
"	Even.	N. W.	29.21	52	A gale, cloudy, with showers.
18th,	Morn.	W. N. W.	29 21	54	Blowing fresh, dark weather and continual heavy rain.
"	Even.	W. N. W.	29.23	60	Fresh breeze, dark W. with rain.

Point of Ayre Lighthouse, lat. 54° 25′, long. 4° 22′. Rain from 11th August, 1840, till 18th, except 13th, — wind westerly all the time, — S. W. on 16th, a gale — N. W. on 17th, gale — 16th and 17th, dreadful days, rain 1.19 inches — barometer on 17th, 9, A. M., 28.88 — 9, P. M., 28.97, — evening before, 29.42.

At Corsewell, lat. 55° 1′, long. 5° 9′, on 16th, S. breeze, rain. At 7, P. M., W. On 17th, N. N. W. storm rain, 1.40 inch, (probably measured in A. M.) On 18th, N. W. breeze, haze, 1.85, (probably preceding night and day.)

[Largs, near Glasgow, Scotland, by Graham Hutchison, Esq.]

1840.	Greatest cold.	Greatest heat.	Diurnal range.	Barometer at 10, A. M.	Heat at 10, A. M.	Wind at 10, A. M.	Diurnal force of wind.	Character of Weather.
August 14,	52	66	14	29.3	60	S. W.	Light.	Cloudy, but dry A. M., a shower, P. M.
15,	51	67	16	29.5	60	N. W.	Moderate.	Dry and clear.
16,	53	68	15	29.6	61	S. W.	Strong.	Cloudy, A. M., rain, P. M.
Wind, 17, S. W. at 3,	48	57	9	28.9	49	N. N.W.	very strong.	Very rainy and stormy all day.
P. M., 18,	49	66	17	29.2	60	N. W.	very light.	Dry but cloudy.
19,	54	66	12	29.6	59	S. W.	Moderate.	Dry but cloudy

Note. Heavy rain commenced on the 16th, at 3, P. M., wind S. W., and rather strong (at Largs). A heavy storm of wind from N. N. W., accompanied with constant heavy rain, commenced on the 17th, at 7 o'clock, A. M., and continued without alteration in the direction of the wind, till 8, P. M., when it subsided. The direction of the wind did not change till next day (the 18th), at 3, P. M., having been nearly calm for seventeen hours previously.

Mull of Kintyre, lat. 55° 19′, long. 5° 49′, W.—Rain on 16th and 17th, 1.45 inch; wind variable on 16th; breezes on 17th, N. W.; gale on 18th, N., breeze, fog. Bar. at 9, A. M., of 17th, 28.80; 9, P. M., 28.70; 9, A. M., 18th, 29.15.

Pladda, lat. 55° 26′, long. 5°, 7′.—15th, S. W., gale, rain; 16th, S., gale, rain; 17th, N. W., breeze; 18th, W. N. W., light airs; rain, in all, 2.10 inch. Bar. 9, A. M., 17th, 29.90 (28.90?); 9, P. M., 28.50.

The Shipping and Mercantile Gazette of 21st of Aug. says — The wind at Greenock on the 16th was S. W., and on 17th, N. and N. W.; and the same paper of 20th, says the wind at Arbroath, N. E. of Edinburgh, was N. E. on the 17th.

Lismore, lat. 56° 30′, long. 5° 38′.—On 15th N. W., breezes, showers; on 16th S. W., strong breeze and rain; on 17th N. W., gale, rain, haze; on 18th N. W., light breeze, haze; rain, in all, 1.34 inch. 17th, 9, A. M., bar. 29.05; 9, P. M., 28.90.

[From William Smith.]

Sir,—I learn that you are anxious to obtain information from various quarters, the direction the wind was in on Monday, the 17th August. I have to state that, at Dumfermline and Kirkaldy, in Fife, at 7 o'clock, A. M., it was direct N.; but that, up till 2, P. M., it increased to a gale, veering to the N. E., when at Kirkaldy it cleared up and subsided. On Tuesday the wind was moderate from the same direction, and the day fine.

Edinburgh, Aug. 16th, 1840. Wind became strong at 4 1-2, P. M., S., 10 pounds to foot on Osler's anemometer; between 7 and 8, 13 pounds; and between 8 and 9, 18 pounds; it then died away till between 6 and 7, A. M., of 17th, when it sprung up from the N. N. E., increasing to 6 pounds a little before 8. It then became moderate, eastwardly, till 2, P. M., when it increased again to 6 or 8 pounds, between 4 and 6, N. N. E. Next morning it was N. by E., from 4 to 5 pounds. It began to rain a few minutes after 10, P. M., of 16th, and by 4 1-2, A. M., of 17th, it had rained, without intermission, one quarter of an inch, and by 8, nearly another quarter, when it stopped till near 10; then it rained hard more than a quarter of an inch, till 1, P. M., when it ceased.

Berwick, (furnished by the P. M., James Foster.) At 4, A. M., Aug. 17th, wind strong, S. by E.; at 6, strong, S. S. E., and so till 12, M.; at 1, P. M., strong, S. E., and so till 6, P. M.; at 7, strong, E. by S.

C.

Storm of December 15th and 16th, 1839.

[See Articles 145 and 146.]

[Norfolk Herald, December 23, 1839.]

1. While a most destructive hurricane, from N. E. to E. was desolating the coast to the east of us, on Sunday the 15th, we had a bright sunny day, and a keen N. W. wind, all day.

2. Journal at Capitol Hill, Washington City. Wind at 3, A. M. of 15th, S. W., light. At 9, westerly, moderate. At 3, P. M., westerly, fresh. At 9, P. M., north west, fresh. Barometer lowest, 29.676 at 3, P. M., having fallen from 29.98 in 24 hours. On the evening of 14th, wind S. E., with 0.38 inches of rain. On 16th, wind W. N. W., at 9, A. M., a gale. Barometer, 29.82. At 9, P. M., wind fresh, west. Barometer, 29.98.

The Montreal Herald of 17th, says, During 14th and 15th there was a plentiful fall of snow.

3. At Cape May, mouth of Delaware, Mr. Miller says, the wind on 15th was N. W., cloudy, with rain, squally.

4. Harrisburgh, Pa. Wind northerly all day.

	Days.	Thermo. A. M.	Thermo. P. M.	Thermo. Even.	Winds. A. M.	Winds. P. M.	Weather. A. M.	Weather. P. M.	Rain. Gage.	
5. Concord, Erie Co.	14	25	30	31	S. E.	S. E.	cloudy	snow		
Lat. 42 30	15	26	28	20	S. W.	W.	cloudy	snow		
Long. 79	16	20	25	24	N. W.	N.	snow	cloudy		
6. Fredonia.	14	32	39	35	S W	S. W.	cloudy	snow		
Lat. 42 26	15	23	36	28	W.	S W.	cloudy	cloudy		
Long. 79 24	16	25	32	26	W.	W.	cloudy	cloudy		
7. Lewiston.	14	27	31	28	S.	E.	cloudy	snow		N. W
	15	26	25	23	S. W.	S.	cloudy	snow	0.13	corner
	16	24	26	25	S.	S.	cloudy	cloudy		of State
8. Steuben.	14	22	36	30	S.	S.	cloudy	cloudy		
Lat. 42 30	15	26	28	20	N. W.	N. W.	cloudy	cloudy		
Long 77 20	16	22	28	22	N. W.	N. W.	cloudy	cloudy		
8½. Monroe.	14	31	35	33	S.	E.	cloudy	cloudy		
Lat. 43 06	15	30	28	27	W.	W.	snow	snow		
Long. 77 39	16	27	26	24	N.	N.	cloudy	cloudy		
9. Homer.	14	22	34	28	S. W.	S. E.	cloudy	snow		
Lat. 42 38	15	29	32	23	S. W.	N. W.	snow	snow		
Long. 76 11	16	27	28	23	N. W.	N. W.	snow	snow		
10. Utica.	14	30	38	36	E.	E.	fair	fair		
Lat. 43° 6′ 49″	15	26	31	24	W.	W.	cloudy	cloudy	0.41	snow
Long. 75 13	16	30	27	24	W.	W.	cloudy	cloudy		
10½. Cherry Valley.	14	25	30	36	W.	W.	cloudy	fair		
Lat 42 48	15	20	25	24	W.	W.	snow	snow	1.33	
Long 75 06	16	23	24	22	W.	W.	cloudy	snow		
11. Oneida.	14	25	38	36	S. W.	W.	snow	snow		snow
Lat. 43° 8′ 15″	15	28	30	29	W.	W.	fair	fair	1.00	on 12,
Long. 1° 46′ 51 E. of Washington.	16	31	36	33	W.	W.	fair	fair		13, 14.
12. Rochester.	14	28	33	30	E.	E.	fair	cloudy		
Lat. 43 08	15	28	24	22	W.	W.	cloudy	cloudy		commenced snowing at sunset of 14th, snowed moderately all day 15th, 2 inches deep.
Long. 77 51	16	26	28	26	N. W.	N. W.	cloudy	cloudy		
13. Lowville.	14	6	30	31	W.	W.	fair	fair		
Lat. 43 47	15	30	31	26	N.	N.	snow	snow	0.82	
Long. 75 33	16	20	26	21	N.	N.	cloudy	snow		
14. Governeur.	14	1	23	21	S.	N.	fair	cloudy		
Lat. 44 25	15	19	20	20	N.	N.	snow	snow	1.28	
Long 75 35	16	24	23	20	N.	N.	cloudy	snow		
15. Plattsburgh.	14	20	28	22	N.	N.	fair	cloudy		
Lat. 44 30	15	26	28	24	N.	N.	snow	snow		
Long. 73 30	16	24	28	26	N.	N.	cloudy	cloudy		
16. N. Granville.	14	28	33	27	N.	N.	cloudy	cloudy		
Lat. 43 20	15	27	28	25	N.	N.	snow	snow	1.00	
Long 73 20	16	20	35	25	N.	N.	fair	fair		
18. Lansingburgh.	14	26	38	28	W.	W.	fair	fair		
Lat. 42 46	15	30	32	32	N.	N.	snow	snow	1.42	
Long. 73 44	16	32	35	32	N. W.	N. W.	cloudy	cloudy		
19. Newburg.	14	18	33	21	S.	S.	fair	fair		
Lat. 41 30	15	16	26	15	W.	W.	fair	fair		
Long. 74 35	16	13	24	19	W.	N. E.	cloudy	snow	0.31	
20. New York, by Mr. Redfield.	17				N.bW. strong	N.W.b W. hard gale.				
21. Mt. Pleasant.	14	32	42	29	N. W.	N. W.	fair	snow		
Lat. 41 09	15	30	33	32	N. W.	N. W.	snow	snow	1.26	
Long. 73 47	16	28	32	32	N. W.	N W.	snow	snow		

17. At Albany and Troy, says Mr. Redfield, the wind, late on Sunday afternoon, according to my best information, was somewhat eastward of north.

The Albany Daily Journal says, Since 10 o'clock, P. M. of 14th, till now, (evening of 15th,) the snow has been falling uninterruptedly. The trees, streets, and houses, are all arrayed in the white livery of winter, and the Evening Journal says the snow has fallen three feet deep.

22. Benjamin Topliff has furnished me with the log of schooner Velocity, in lat. 36 44, lon. 69 3, which had the wind, on the morning of the 15th, from the S. S. W. and S. S. E. — wind not given in the afternoon.

It would be highly desirable to know how the ship Morrison had the wind on the morning of the 15th, up to noon. Mr. Redfield says she was in lat. 39 35, lon. 71 38, at sunset — a violent gale, wind W. N. W.

23. Also, Mr. Joseph Congdon, of New Bedford, has sent me an "extract from the log-book of brig J. Munroe, which arrived at that place on the 30th December, which was S. of Long Island, in about lat. 39 or 40, for many days before and after the 15th. The longitude is not given; but it was probably between 73 and 74. Indeed, it is almost certain that she was a short distance W. of Culloden Point, as the wind changed round from E. S. E. to W. N. W. one hour with her before it changed at Culloden. "On the morning of the 14th she had strong gales N. W. by W. At 1, P. M., calm; at 6, P. M., wind S. E., thick, rainy weather; at 3, A. M., of 15th, E. S. E., strong gales and rainy; at 9, do., heavy gales; wore ship to S. W., and hove to at 11, wind W. N. W. At 12, lat. 40 18. The brig did not make sail till 21st, in lat 37 50, long. 73 41, and the storm continued till the 17th, A. M., N. W.

24. I have received Capt. Green's account of the wind at Culloden Point, on the west side of Long Island, some miles south west of Montauk Point, at the eastern extremity of the land. "On the 15th, from 7 to 12, A. M., wind N. E. Snow from 8, P. M., of preceding evening. At 12, M., wind suddenly veered N. W., and continued near that point till Tuesday noon."

25. The New Haven Daily Herald of 16th says: "About 7, P. M., of 14th, snow commenced and continued till next evening. About 12, of 15th, Boreas is beginning to pipe from the N. W. a tune of icy coldness. The snow fell very much and level, about 20 inches deep; not much wind at the beginning."

[By Benjamin Pendleton.]

26. At Stonington, during the most of the day and the greatest violence of the storm, the wind varied from E. N. E. to N. N. E., strong and heavy.

At Block Island it was E. N. E., moderate, and 20 miles to the south of Block Island was east southerly, moderate gales and strong breezes.

[By James Mitchell.]

27. *Nantucket.* Saturday afternoon, the 14th, it was nearly calm, light air northerly, clouds increasing, thickening especially in the west. During the night the wind came from the eastward, and, in the morning at 7, was about N. E., blowing a heavy gale, but no part of the

gale was considered as extremely heavy. It rained and snowed violently during the forenoon, the wind veering to the E., and is given by Mr. Folger at E., at noon. About 1, P. M., it being very dark, wind S. E., and blowing the hardest, there were several claps of thunder, one sharp flash of lightning, attended with rain and large hail stones. In 30 minutes or less, from this time, the sun made its appearance, the wind having changed to S. S. W., and became quite moderate. There was no rain during the afternoon. It was overcast, the clouds light, of yellow brown appearance, similar to those we notice after a thunder storm in summer, at times.

METEOROLOGICAL JOURNAL.

Nantucket, Dec. 16*th*, 1839.

Days of Obs.	Hours of Obs.	Bar.	Therm.	Course of Wind.	Weather.
14	7, A. M.	29.99	33	W. N. W.	fair.
	12, M.	29.97	37	N. W.	do.
	9, P. M.	29.93	32	N. E.	do.
15	7, A. M.	29.53	36	E.	rain.
	12, M.	29.13	42	E.	do.
	9, P. M.	29.05	36	S. W.	fair.
16	7, A. M.	28.96	38	N. E.	cloudy.
	12, M.	29.03	44	N. N. E.	fair.
	9, P. M.	29.32	35	N.	rain.

28. At Provincetown, near the north extremity of Cape Cod, the gale was most severe from 11 to 4, P. M., on Sunday; its direction, by collating the accounts, would appear to have been from E. S. E. During the night following, the wind is stated to have been moderate, and all round the compass. This was the central lull, as the storm was renewed on the following morning, as well as at the above mentioned places.

[By S. Rodman, Esq.]

29. *New Bedford.* 14th, wind N. W. at 2, P. M., and at sunset and 10, P. M., eastward, light. 15th, at sunrise, eastward, fresh, and snow; at 2, P. M., E., very high; at sunset S. S. E., high; at 10, P. M., southward, light. 16th, at sunrise, N. E., fresh; at 2, P. M., N., high; at sunset N., high; at 10, P. M., N. W., high; snow storm all day 16th and 17th; 2.33 inches in water. The barometer, on morning of 14th, 30.07; morning of 15th, 29.53; at 10, P. M., of 15th, 29.11; on the morning of 16th, 29.14, and at 10, P. M., 29.53.

30. At Woonsocket Falls, fifteen miles N. of Providence, Mr. Green's Journal gives the wind N. E. till 6, P. M., then E. Great snow, $3.\frac{50}{100}$ inches of water when melted. Barom. 28.41 at noon of 16th; minimum not given. Snow continued on 16th, wind N. E. On 15, at noon, barom. 28.45.

31. The Boston Courier, of the 18th Dec., says: "We learn from Captain Slemmer that he was off the pitch of Cape Cod, on Friday, P. M., when he took a gale from W. N. W., and was blown off about 80 miles. On the 15th, 2, A. M., he had a light breeze from E. S. E. At 5, it freshened, with snow. At 11, he made Cape Cod again, and was obliged to reef down close; his barometer standing then at 29 5.10. Passed Race Point at noon, stood over, and made Sandwich at 2, P. M., it then blew a hurricane from E. S. E."

The same paper of the 17th, says: "From Barnstable. — A gentleman who left Barnstable in the stage early yesterday morning, informs us that the storm at that place was neither severe nor disastrous. At 7 o'clock on Sunday morning, the wind was at N. E., with some snow, which soon changed to rain. It blew freshly during the forenoon, but not sufficiently strong to occasion any damage ; and in the afternoon the wind came round to E. and S. E., and was S. at sun set, rather mild, and stars were visible in the evening."

"31½. Schooner Friend, from Boston to N. Y., on Saturday the 14th, at 7, A. M., passed Sandy Point, Nantucket, with gales W. N. W. all day, till half past four, when it died away and became calm. At 10, P. M., commenced fresh gales from E. N. E., and continued on the morning of the 15th, with snow and rain, continuing to increase to a hurricane, with snow and hail. At 3, P. M., began to moderate ; breakwater, mile and a half astern. At midnight, on the 16th, N., fresh breezes. At 8, A. M., thickened, wind veering to the eastward. At 8 h. 30, commenced snowing, wind E. N. E. We hauled to the northward for Tarpauline Cove. Continued to storm through the day, wind heavy from N. E. by N. At midnight, cleared up, and wind hauled to N. N. W. At 7, on the 17th, weighed anchor, and at 9 h. 30, passed Elizabeth Islands. Ship all this time was E. of New Bedford and N. of Nantucket."

This log was kept by Edward S. Johnson, U. S. N.

32. The Boston Atlas of the 16th Dec., says: " A snow storm commenced yesterday morning about 3 o'clock, and continued until 2, P. M., when it commenced raining, with a violent gale from the N. E., which lasted till 7, P. M. The wind then shifted to the S., and the gale abated, but still raining."

[Dorchester, (two miles and a half south of the State House in Boston.) 1839. Gale of December 15. Civil account.]

Force of the wind, 0 *to* 6. *Clouds*, 0 *to* 10.

14th. Saturday noon. Bar. 30.038 Int. Ther. 45. Ext. 36. Wind N. W. Force 2.

Sunset. Bar. 30.036. Int. Ther. 48. Ext. Ther. 30. Wind N. W. Force 1. Cloudy 4 ; wane ; during the evening, gathering' to nimbus a lunar circle ; hor. diam. 40°, elongated toward the southern part of the horizon near two degrees.

15th. Sunrise. Bar. 29.576. Int. Ther. 47½. Ext. 30. Wind N. E. Force 3. Clouds 10. Snow. Min. Ther. 29, Max. 42, for the preceding 24 hours.

Noon. Bar. 29.422. Int. Ther. 50½. Ext. 32. Wind E. N. E. Force 3½. Cloudy 10. Snow storm.

Sunset. Bar. 29.048. Int. Ther. 49. Ext. 38. Wind E. S. E. Force 3½. Clouds 10. Stratus. The greatest force of the wind was from 11 to 13 hours. At midnight, the Bar. indicated 28.942 inches. Wind from E. S. E. to N. E.

16th. Sunrise. Bar. 29.218. Int. Ther. 41. Ext. 30. Wind N. E. Force 4. Cloudy 10. Snow.

Noon. Bar. 29.244. Int. Ther. 44. Ext. 30. Wind N. E. Force 2½. Cloudy 10. Snow.

Sunset. Bar. 29.338. Int. Ther. 44. Ext. 30. Wind N. N. W. Force 2½. Cloudy 10. Snow.

17th. Sunrise. Bar. 29.724. Int. Ther. 38. Ext. 26. Wind N. W. Force 1. Clouds 7. Wane.

Noon. Bar. 29.740. Int. Ther. 47. Ext. 31. Wind N. W. 1. Cloudy 0.

Barometer by Cary. Brass scale. Lower surface of the mercury always adjusted. Diam. of tube, 0.18 of an inch. Height above mean level of the sea, 18 feet.

33. A published letter from Gloucester, north eastern extremity of Massachusetts bay, dated on Sunday night, says: "We have experienced a most disastrous gale of wind here to-day, from E. S. E. The rain continues to pour in torrents, and the gale has not abated any."

At Salem, 15 miles from Boston, according to the Salem Register, "During the day, at intervals, the wind blew with tremendous force from the eastward, and the rain fell in torrents."

34. At Newburyport, 30 miles N. N. E. from Boston, according to the Newburyport Herald, the storm commenced on Sunday morning, 15th, and "from 10 to 12 o'clock on Sunday night, the wind, which had shifted a point or two more to the N. E., blew a perfect hurricane."

35. At Portsmouth, N. H., some 60 miles N. N. E. of Boston, in the Meteorological Journal, published at that place, we find the wind recorded, during the day, at East, with snow and rain. In a Portstmouth paper, this storm is styled a "heavy N. E. gale.

[Portland, Maine, by Lemuel Moody, Esq.]

36. December 14th. Commenced, with moderate N. W. winds, clear and pleasant. Noon, quite calm. P. M., light northern airs, clear but at times a few clouds. Evening, cloudy. Thermometer at sunrise, 25 degrees. At noon, 32 degrees, at 8, P. M., 25, in the true current of air.

Sunday, 15th, at 7, A. M., a fresh breeze from N. E. and cloudy, with flurries of snow, at 11, A. M. Wind east, with moderate rain. At 12, noon, quite a gale, and heavy rain ; wind all the afternoon, E. by S., to E. N. E., rainy, and at times snow; powerful wind; snow falling moderately through the night, with a strong gale from E. N. E. to N. E.

The Journal of the Portland Observatory, says: 14th. Light N. W. wind and clear; noon, nearly calm; P. M., light N. W. airs; evening cloudy. 15th. In the morning, strong N. E. wind and some snow ; at 11, A. M., wind east with heavy rain; P. M., E. by S., gale still continued ; in the evening wind shifted to the N. E. and snow fell most of the night, with no abatement of the gale. 16th, N. E. storm continued through the day, snow not falling very fast but strong wind; evening, storm ceased.

37. [Eastport Maine. From the Sentinel.]

Day.	Barometer.			Thermometer.			Winds.	Weather.
	7 A. M.	2 P. M.	10 P. M.	7 A. M.	2 P. M.	10 P. M.		
15,	29.92	29.75	29.63	36	38	37	N. E.	Rain.
16,	29.48	29.45	29.49	34	37	35	N. E.	Rain.

[Waterville College, (Me.) by George W. Keely.]

37½ Day	Coldest Temp. between preceding sunset and sunrise.	Barometer at sunrise.	Thermometer attached.	Barometer at noon.	Thermometer attached.	Barometer, 2 P. M.	Thermometer attached.	External Ther. 2, P. M.	Barometer 9, P. M.	Thermometer attached.	Wind. S. R.	Wind. 2 PM.
15th	18	29.84	49	29.69	63	29.65	63	34	29.59	71	N. E.	N. E.
16th	29	29.48	52	29.49	51	29.52	48	32	26.64	52	NNE.	NNE.

14th. Sunrise, cloudy. Do. during most of the day. Corona round the moon at 8, P. M.

15th. Sunrise, clouded, snowing; very little snow falls; a very little falls at times during the day.

16th. Strong wind during past night, and considerable snow fallen; snow falls during most of forenoon, then ceases; perhaps in the whole five inches fallen, much drifted. Evening wind, N. N. E.

[From J. Sleeper, Esq., Editor of Boston Evening Journal.]

Dear Sir, — I have learned to day, that the ship Robin Hood, was out in the gale of the 15th December, 1839, to the eastward of the southern point of Nova Scotia, say 300 miles off. The gale was tremendously heavy there, and the ship was near foundering; wind from the eastward.

38. At Concord, N. H., Mr. M. G. Thomas. At 5, A. M., of 15th, the ground was covered with snow; wind varying from E. to N. At noon, strong N. E.; and in P. M., wind very violent from N. of N. E. On 16th, strong most of the day, and abated N.; snow twenty inches deep by night.

39. At Springfield, N. H., Mr. J. Nevins gives the wind during the whole day of 15th, a little N. of E., and the same on 16th; and he says the wind was very strong, throwing the snow into heaps. Commenced snowing very fast at 4½, A. M. of 15th, continuing till night of 16th.

At Smithtown, Long Island, near the middle, Mr. Mills gives the wind N. E., with snow in the morning, N. W. in the afternoon, with a clearing up. Snow two feet deep, much drifted.

40. At Burlington, Mr. Thompson by Mr. E. Mills, P. M., gives the wind all day the 15th, N. E., and on 16th, N., with snow all day the 15th and morning of 16th, wind not strong enough to drift the snow materially on 14th. Wind N. W., 0.73 inches of water fell.

41. At Bennington, Mr. J. Hunt says, on 15th, snow, wind N. W. 16th. snow, wind N. W., snow twenty inches deep. There was but little wind. And Mr. Kellog says, on the 15th, the wind was N. W., very gentle, and snow fell during the storm, two feet deep.

[Amherst, Mass. by Professor E. S. Snell.]

1839.		Bar.	Ther.	Wind.	
Dec. 14,	9, A. M.	29.78	30°	N. W.	Some haze in South.
" 14,	3, P. M.	29.77	36	N. W.	Thinly clouded over, moving from S. W. Snow began in night.
" 15,	9. A. M.	29.36	26	N. by W.	Snows fast from W. of N.
" 15,	3, P. M.	29.00	28	N. by W.	No abatement of the storm.
" 15,	7. P. M.	28.90			Bar. begins to ascend slow after 7.
" 16,	9, A. M.	29.14	28	N. W.	Storm continues with some abatement.
" 16,	3, P. M.	29.26	28	N. W.	Snows but little after noon, clears at evening, 18 inches of snow, making 2.65 inches water.

All Sunday, (15th,) the wind was slightly W. of N. I did not perceive it N. E. at all.

43. At Northampton, Mr. C. A. Hall says, during the storm of 15th, the wind was very strong and north exactly, or if it varied at all, it was a little east of north. It began about 1, A. M., and the barometer fell from 29.88 to 29.05, and Mr. Shepherd gives the wind N. all day, with barometer lowest at 4½, P. M., having fallen from the eve of 14, from 29.94 to 29.13, and on 16th, N. all day, cloudy.

44. Mr. Gideon Welles, of Hartford, says: "During the storm of the 15th, the wind blew from the north west during the whole day. Towards evening it varied a point, perhaps, towards the north."

Mr. George Halsey, of River Head, near the eastern end of Long Island, says, on the 14th, at 8, P. M., the wind was E. S. E., at 1 o'clock, A. M., of 15, due E., and at 2, do.; commenced snowing. At 10, wind N., afternoon.

At Providence, R. I., according to the observations of Professor Caswell, of Brown University, the wind on the 15th was "brisk at N. E., which continued till 2, P. M. The barometer continued to fall till 4, P. M., and remained stationary till near 7, P. M., and the wind still at N. E. and cloudy." The Professor adds, "I am not particular to mark the *exact* point of compass, nor, indeed, have I any means of doing so." It appears probable that this locality was in or near the border of central lull, after 2, P. M.

At Middletown, Ct., as I am informed by Professor Smith of the Wesleyan University, the gale set in at N. N. E., and continued to snow and blow very hard during the 15th; the wind rather veered round to N., in which quarter the wind was very strong at the close of the day.

At Nashua, N. H. on the Merrimack, as we are informed by the Nashua Telegraph, "the storm of the 15th was from N. E."

Mr. Redfield says: At Athens, Hudson and Catskill, from information on which I can place implicit reliance, the wind at this time was north, and near New Haven, Ct., off the light house, Captain Woolsey, of the steam boat Providence, informs me that on Sunday afternoon till near sunset, the wind was strong at N. N. W.; but at 9, P. M., it had veered to N. W. and was very heavy.

[From the Boston Mercantile Journal.]

Mr. Editor — I learn from your paper of the 14th inst., that Mr. Espy stated in his late lectures, that the observations of the storm of December 15th, which I published, " were taken in the evening after the storm had passed away;" and that to prove any thing, these observations " should have been made in the middle of the day."

To answer this, I need only say, *first*, that on putting down the observations made at *noon* on that day, I find the same general result as in the statements and diagram before published, viz: *a circuitous course in the wind which was moving around the centre of the storm:* This centre, at noon, being of course in a different location from that found at sunset.

W. C. Redfield.

New York, 18*th Jan.* 1840.

Mr. Redfield says this storm blew in a great circuit round its central portion in the direction which is contrary to the hands of a watch which lies with its face upwards, as is found to be the case in all gales which he has examined, not excepting even those upon which Mr. Espy is accustomed to rely, in his attempts to sustain his favorite hypothesis of a centripetal motion!! Let the candid reader judge who makes hypotheses. I disclaim them.

D.

Mr. Espy's Paper, read at the meeting of the British Association.

[From the London Athenæum, Oct. 1840.]

Mr. Espy read a paper at the meeting of the British Association, to show that the four fluctuations of the barometer which occur daily, are produced entirely by the increasing and diminishing elasticity of the air, due to increasing and diminishing temperature. When the sun rises, the air begins to expand by heat; this expansion of the air, especially of that near the surface of the earth, lifts the strata of air above, which will produce a reaction, causing the barometer to rise; and the greatest rise of the barometer will take place when the increase of the heat in the lower parts of the atmosphere is the most rapid, probably about nine or ten, A. M. The barometer, from that time, will begin to fall; and at the moment when the air is parting with its heat as fast as it receives it, the barometer will indicate the exact weight of the atmosphere. The barometer, however, will continue to descend on account of the diminishing tension of the air, and consequent sinking upon itself, as the evening advances, and its greatest depression will be at the moment of the most rapid acceleration of diminution of temperature, which will be about 4 or 5 o'clock. At this moment the barometer will indicate a less pressure than the true weight of the atmosphere. The whole upper parts of the atmosphere have now acquired a momentum downwards, which will cause the barometer to rise above the mean, as the motion diminishes, which must take place some time in the night. This rise will be small, however, compared with that at 9 or 10 A. M. As the barometer now stands above the mean, it must necessarily descend to the mean at the moment when the air is neither increasing nor diminishing in temperature, which will be a little before sunrise. If this is a true explanation of the four daily fluctuations of the barometer, it will follow that the morning rise ought to be greater at considerable elevations, provided they are not too great, because some of the air will be lifted above the place of observation; and such was found to be the case by Col. Sykes,[1] in India. As this morning rise of the barometer depends on the increasing elasticity of the air, and this increasing elasticity, on heat, Mr. Espy proposed to the mathematicians to calculate how much the whole atmosphere is heated from sunrise till the time when the barometer stands highest, the actual rise of the barometer being given. In this way, as refraction is affected by temperature, meteorology may assist astronomy.

Professor Forbes doubted the correctness of Mr. Espy's views of the cause of the great daily fluctuation of the barometer at elevated stations; for, towards two or three o'clock, the heat being greatest, its effect in lifting up the inferior air to and above the elevated station should then be greatest, whereas that time of the day was nearer to the time of minimum height of barometer than its maximum.

To this Mr. Espy answers, that at very great elevations, it is probable from the theory there would be only two fluctuations in a day, the maximum at the moment of the greatest heat, and the minimum, at the moment of the greatest cold. But at moderate elevations, such as from 1800 to 2000 feet, the effect would be to prolong the time of maximum a few minutes at the upper station, so that it might still be rising above, after it began to descend below.

Experiments were wanting to determine this matter.

The principle itself, as a *vera causa*, is too plain to admit of doubt. It is the mere application of the law that "action and reaction are equal and in opposite directions."

It might, however, be illustrated in the following manner.

Let a person balance himself in a pair of large scales, in a stooping position. Now he cannot raise himself erect, without causing the scale in which he stands to descend, he cannot come to rest in an erect position without his scale again rising, to equilibrium. He cannot stoop down again, after a balance, without his scale rising, at the moment his motion downwards commences, he cannot diminish his velocity downwards, without increasing his pressure on the scale beyond his natural weight, and causing his scale to descend again beyond equilibrium; and finally he cannot come to rest without producing equilibrium; and thus he will produce four oscillations of the balance by one upward and one downward motion of his body, corresponding to one expansion and one contraction of the air in the day.

[1] Col. Sykes found the nocturnal falling minimum tide from 10—11, P. M., to 4 — 5, A. M., at Poona, .0181 inches from about 2000 to 1800 feet high; and the diurnal rising tide, from 4—5, A. M., to 9—10, A. M., .0445 inches; and at the height of 4500 feet, he gives these same tides .0240 and .0636, and at the height of 6407 feet, .0433 and .0490, as observed by Dr. Walker and M. Dalmahoy. [Roy. Phil. Trans. for 1835 p. 196.]

Phenomena of an Aurora,

Which appeared at Woolwich, ten miles east of London, and at Gosport Observatory, 75 miles S. W. of London, on 7th of January, 1831. (See Phil. Mag., vol. 9.)

Hour. Gosport Time.	GOSPORT.	WOOLWICH.
Hours. Min. 5 15	Arch of refulgent light 10° high.	Arch of faint yellowish light, not more than 10° high, dense black area below it to horizon.
5 30	Bright flame-colored, rainbow-like arch, 3° or 4° broad, rose from the upper edge of aurora to the height of 35°, and, at the same time, a beautiful rainbow-like arch formed 10° south of the zenith, by streamers suddenly springing up from the N. E. by E. and W. by S. points of horizon, meeting.	As above, only a little higher and more brilliant and darting, occasional faint flashes from a bright and apparently steady luminous curve.
5 35	This arch began to break up into patches and pass off to the south, continuing in sight 15 minutes.	As before.
5 40	Another arch, in all respects like the former, formed in the same place.	As before.
5 45	This last bow had moved south to 45° altitude.	As before.
6	It was near the S. horizon hardly visible.	As before.
6	Bow over the aurora much increased in altitude and nearly effaced.	As before.
6 5	A great many colored columns of light rose from the N. E. and N. W., and passed the zenith, and the aurora sunk towards the horizon.	As before, rising a little.
6 30	Aurora increased in altitude and vivid corruscations radiated from every part of the arch, and on mingling with each other, formed wide columns which were so grand with crimson tints as to astonish every spectator.	A second, and apparently concentric arch, of bright light, made its appearance 10° above the auroral arch, or 20° high, and soft lambent streamers played from the lower even beyond the upper, but not so as to obliterate the distinction of the two.
Between 7 & 8	The aurora had spread over two thirds of the heavens, when	As before, only the arch rose to 24°, and the auroral

Hours. Gosport Time.		GOSPORT.	WOOLWICH.
Hours.	Min.	large perpendicular columns and short pointed corruscations, rising from the aurora in nearly parallel rows, all passed through red, orange, lake, crimson, green, and purple tints.	light, 14°, keeping the same distance apart.
7	55	Another rainbow-like arch stretched across the heavens from the eastern point of the horizon, and passed off to the south.	As before.
8		The aurora gradually diminished, and a large tenebrous space in and near the horizon, on each side of magnetic north, appeared.	As before.
9		Aurora rose again, and wide columns rose from every part of its arch, and passed through the same colors as before.	As before.
9	30	As before.	Increased in splendor; shot up streamers from external bow nearly to zenith.
9	45	As before.	A faint stream of light kindled in the eastern extremity of external bow, and in a moment described an arch of 100° through the tail of U. M.
10	25	As before.	Similar streamers from the western end of exterior arch.
10	45	Grand display of 12 or 14 columns glowing from the aurora, some passing the zenith, and a perfectly red rainbow-like arch appeared 10° above the aurora.	Streak of bright light, like a yellowish cloud, stretched horizontally towards the east, a moment after a streamer kindled at its eastern extremity, and shot gradually upwards past the meridian, undulatory streamers began to play in every part of the north, reaching nearly to the zenith, dense central darkness disappeared, and bright light reached horizon for first time.
11		Another bow, 3 1-2° wide, rose from the aurora, and soon reached the zenith and gradually disappeared.	Dark spot again appeared, with bright streamers from its upper side.

[Aurora of 17th November, 1835.]

At Schenectady, New York, it rained or snowed every day, from the 10th till the 16th, and on the 17th, there was a brilliant aurora at Germantown, reaching from the north star to the zenith, when, at the same time, precisely, at Philadelphia, five miles south of Germantown, the aurora was very faint, and did not reach above Lyra, Polaris, and Capella. At New York, it reached from the northern horizon, 12° south of the zenith, and along the horizon to south by east, and south by west; while at Providence, Rhode Island, as described by Professor Caswell, it never extended beyond the zenith, and only reached along the horizon as far as N. W. and N. E. All these have been evidently different auroras, they must have been low in the atmosphere.

The preceding phenomena, and many others, which I have not room to insert, render it certain that the aurora is sometimes low in the atmosphere.

[From the Edinburgh New Philosophical Journal, for October to January, 1840, page 413.]

Mr. Espy's Theory of Atmospherical Phenomena claimed by Mr. Meikle, of Edinburgh. Respecting Mr. Espy's theory of atmospherical phenomena, the leading feature of which, is the fall of temperature which occurs in an ascending current of air, we are requested, by Mr. Meikle, to state, that, in the London Quarterly Journal of Sciences, for April, 1839, and in the article Hygrometry of the Encyclopedia Britanica, vol. XII. p. 132, he has distinctly laid down the same theory in detail, and accompanied it with various calculations and illustrations, which show how it will satisfactorily account, not only for the production of clouds, mountain caps, rain, snow, &c., but also for thunder, lightning, and water-spouts, if not some of the phenomena of volcanoes, and the northern lights.

To do justice to Mr. Meikle's claim, I have copied from the Ency. p. 135, the following paragraphs.

"The sound (in thunder,) may be partly a tremor, which the air sustains, at the moment the pressure is relaxed by the vapor suddenly losing the elastic form, and may be partly a tremor due to an effort of the electricity to make its escape from the cloud.

Page 134. "It is evident that moisture which has ascended in the form of transparent vapor, and descended again as rain, snow, &c., must have left its latent heat above. But much heat, no doubt, moves upward from its natural propensity to render the atmosphere of one temperature throughout its whole height, and from the tendency of warmer air to rise above the colder. There is, therefore, good reason for concluding that air which has just been elevated and dilated should be thereby reduced to a much lower temperature, than what obtains in air, which has remained at that elevation for some considerable time, receiving heat from below, from the sun, or other sources."

The principle of the dew point has many applications highly useful. One is given here as a specimen of its connexion with medicine. Others might be adduced of its connexion with the refraction of light in the atmosphere, and of its power in predicting a change of temperature many hours before that change takes place, by its sudden rise or fall; but these are omitted for want of room.

It is known that the quantity of vapor in the air, by weight, may be ascertained at any time by the dew point. So, also, the quantity at any time in the breath, expired from the lungs, may be known by breathing on a bright metallic tumbler of water, and finding the highest temperature at which the vapor will condense upon it.

I have performed this experiment frequently, both in summer and winter, and I find the dew point of my breath, and that of several others, 94° of Fahr.

Now, by examining a table of the elastic force of vapor or dew points by Dalton, it will be seen that when the dew point is 94° the elastic force of vapor is 1.53 inches of mercury in the barometer; and as vapor is known to be only five eighths the specific gravity of air, it may easily be calculated that the vapor in the breath is about one thirty-first part of the breath in weight; that is, of thirty-one pounds of the breath expired, if the dew point is 94°, thirty pounds will be air, and one pound vapor. This quantity is always much more than that which is inspired; for the dew point of the atmosphere is never more than 80° in this climate, and in the winter it is sometimes much below zero. Whatever it may be, it can always be known, and of course the quantity inspired with different dew points can be known. Therefore, if the quantity inspired should be ascertained, and subtracted from the quantity expired, the remainder will be the quantity evaporated from the lungs themselves.

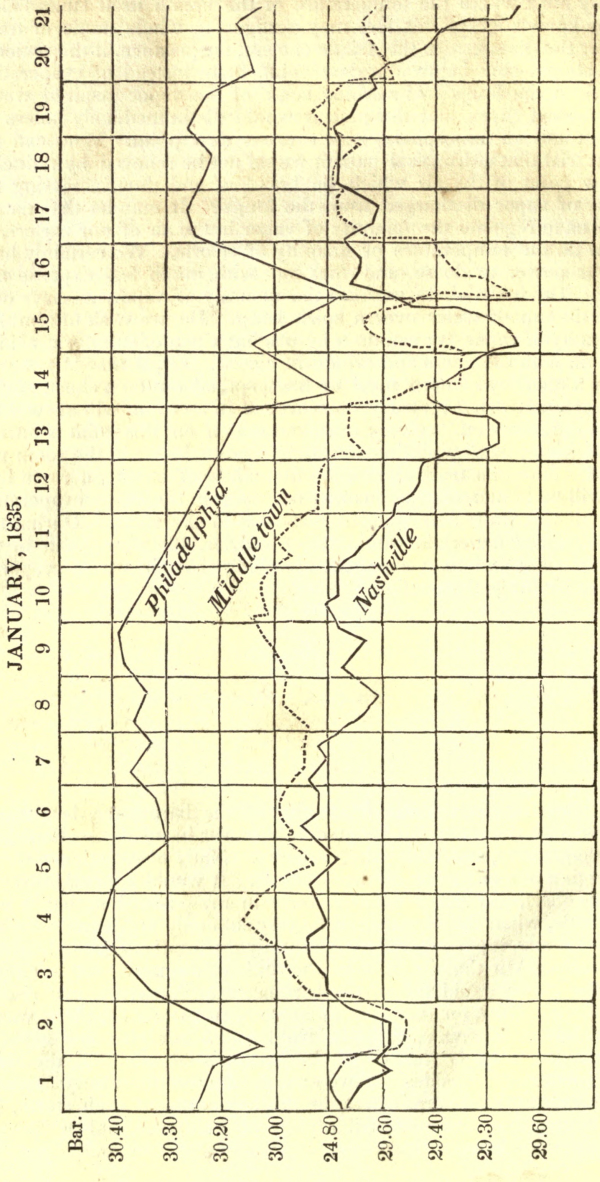
According to this principle, I have made the calculation of the quantity of vapor discharged from the lungs, by subtracting the quantity inspired from the whole quantity expired, supposing the dew point of the breath, on expiration, to be constantly 94°, as I have always found it to be.

It results from this calculation, that when the dew point is 32°, we evaporate from the lungs one pound of vapor for every thirty-five pounds of air which we breathe. And when the dew point is 75° we evaporate from the lungs one pound for every sixty-nine pounds; so that in summer, when the dew point is very high, we evaporate from our lungs only about half as much as we do in winter, when the dew point is very low. Moreover, it will appear by calculating according to principles developed in article (9), that the latent caloric contained in one pound of vapor, at the temperature of the breath would be sufficient to heat thirty-five pounds of air, about 130°, and therefore the air which we breathe at the temperature of 32°, brings out with it in the vapor alone, sufficient caloric to heat it 130°. And if to this we add the number of degrees it is actually heated, from 32° to 98°, it will appear that when we breathe air at 32°, the lungs part with a sufficient quantity of caloric to heat all the air we breathe 196°. This calculation is made on the supposition that no vapor is generated in the lungs by the union of oxygen and hydrogen.

M. Pouillet, however, (506,) says that Dulong, in a series of experiments, not yet published, has shown that some oxygen disappears in respiration, besides that which unites with carbon to form carbonic acid, and he seems to think it probable that it unites with hydrogen to form water; if so, it will modify the result given above.

The whole subject is worthy of further investigation. If it should be found that the dew point of the breath changes with some diseases, as it certainly must where the temperature of the breath itself sinks below 94°, the knowledge of this fact may change the whole mode of treatment for the disease. In the Asiatic cholera, for instance, if the patient's breath should sink below the dew point, then, instead of evaporating water from the lungs by breathing, some of the vapor inspired would be condensed there, and the patient would die immediately unless he were put into an atmosphere with a lower dew point. Who can tell without trial that a dropsical patient would not be relieved by reducing the dew point of the air which he breathes, and thus increasing the quantity of vapor discharged from the lungs? It may be that nature intends us to regulate the quantity of vapor in the air of our parlors, as we now do the temperature or quantity of caloric. We certainly have it in our power to do so, and that too with much less expense and trouble. Do we wish to increase the quantity of vapor, we have only to set a tin cup of water over a spirit lamp. Do we wish to diminish the quantity of vapor, we can do it by placing a pan of sulphuric acid in the room, with the doors and windows closed. Or, if that is not convenient, a quantity of corn meal or bran, spread out on a sheet, having been previously dried very dry, or scorched in an oven, will answer the purpose quite as well. A very mistaken notion on this point is universally prevalent, that by putting fire into a stove the air in the room will be dried. Now the truth is, that the first effect of heating a room by a stove, will be to increase the quantity of vapor in the air by evaporating it from all the walls and wooden materials in the room. During this operation these materials would become drier, the dew point in the air would rise; and then a patient breathing this air would evaporate less from his lungs than before.

The following chart of the fluctuation of the barometer, is given as a specimen of the manner I adopted to discover in what direction these fluctuations move, and with what velocity. Many observations are yet wanting to make out a law on these points. It would appear, however, from this chart, and others which I have in my possession, that it is a general rule, when the barometer falls very suddenly at Nashville for ten or twelve hours, it rises with great rapidity during those same hours at Middletown. On the morning of the 29th of January, for example, there was a very rapid fall of the barometer at Nashville, and rise at Middletown. Now, on that day, as appears in article 30, there was a storm of rain at Nashville, with the wind at Philadelphia and Middletown blowing towards Nashville. In Loomis's storm, (170), the same result is obtained. Besides, I have examined more than forty cases of great storms at Baltimore, where, at the beginning of each storm, for many hours, the barometer fell rapidly at Baltimore, and at Boston, during the same hours, it rose.


JANUARY, 1835.
Philadelphia
Middle town
Nashville
Bar.
30.40
30.30
30.20
30.00
24.80
29.60
29.40
29.30
29.60
1
2
3
4
5
6
7
8
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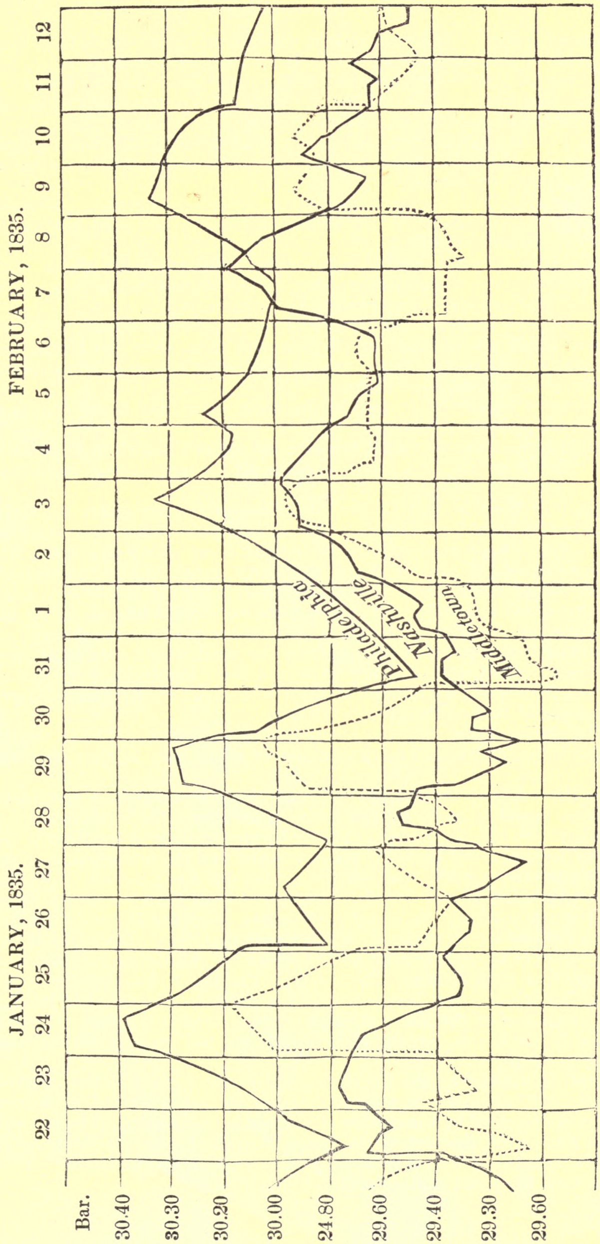
JANUARY, 1835.
FEBRUARY, 1835.
22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12
Bar.
30.40
30.30
30.20
30.00
24.80
29.60
29.40
29.30
29.60
Philadelphia
Nashville
Middletown

On the Helm Wind of Crossfell. By the Rev. J. Watson. Eighth Report of the British Association.

"This wind is applied to a very violent wind, blowing frequently from some eastern point of the compass, at the west side of the Crossfell range, and confined, both in length and breadth, to the space between the Helm and Helm Bar. The western front of the Helm is a long, large roll of clouds, clearly defined, and quite separated from any other cloud on that side.

The Bar has its eastern front as clearly defined, and at the same height. On the west side of the Bar there is either no wind, or it blows in a contrary direction, that is, from the west.

Neither the Helm nor the Bar are separate or detached clouds, but rather the bold, clearly defined fronts of clouds, extending eastward behind the Helm, and westward from the Bar.

The open space between these clouds may be called a very flat ellipse, eight or ten, or even twenty to thirty miles long, and from one half to four or five miles wide. They appear always united at the ends.

The open space between the Helm and Bar is clear of clouds, with the exception of small pieces breaking off now and then from the Helm, and driving rapidly over to the Bar; through this open space is often seen a higher stratum of clouds, quite at rest.

It is seldom accompanied by rain in the open space, and never continues long after it begins to rain heavily."

If it should be ascertained that it rains on the top of Crossfell at the time of the Helm wind, it would be easy to explain all the phenomena mentioned above.

The weight of the rain, and its cooling effect on the air under the Helm cloud, would depress the air under the cloud, and press it out on all sides below, with a velocity proportional to the height from which the drops fell. This outward motion of the air below would not reach to any considerable height, and the air above would be running towards the Helm cloud, and upwards in that cloud to supply new vapor to be condensed into cloud by the cold of diminished pressure. The air which rushes out from the falling rain below, meeting that which was coming from the west, would soon be stopped in its motion outwards, and in rising up would form the Helm Bar; and as it rushed out from the very bottom of the Helm cloud itself, it would carry with it portions of that cloud towards the Bar.

Up in the region of the Bar the air at the same time would be in motion towards the Helm, and would carry portions of cloud over in that direction with it.

If this is the true explanation, several other facts besides those mentioned below will be found to exist at the time. Rain under the Helm cloud — a colder air between the Helm cloud and the Helm Bar than to the west of the bar — a smaller difference between the dew point and the temperature of the air, between the two clouds, than on the west of the Bar; the top of the Bar vastly lower than the top of the Helm cloud; though their bases may be on the same horizontal level; the cloud that passes from the Helm to the Bar underneath the one which passes from the Bar to the Helm; the edges of the Bar seldom if ever so well defined as the edges of the Helm, and never so dense nor so free from motion, the lower part of the Helm and the upper part of the Bar which cross over towards each other, and frequently a jutting out of the upper part of the Helm cloud, so as to overhang the Bar. If these phenomena do not accompany the Helm wind then the above is not the true *rationale*, if they do, it is.

It may still be asked why the Bar cloud, when once formed by the upward motion of the air, dissolves in a great measure on being pressed or driven towards the Helm cloud by the motion of the air in that region. The answer is, that the air curves downwards in going from the Bar to the Helm as it does in passing across a hollow between two mountains, and in coming under greater pressure the cloud is dissolved.